HANDBOOK

OF

CONSTRUCTION EQUIPMENT

WORKS OF RICHARD T. DANA

Handbook of Construction Equipment

Handbook of Construction Plant

Cost Analysis Engineering

By GILLETTE & DANA

Mechanical & Electrical Cost Data

A handbook

Cost Keeping and Management Engineering

Construction Cost Keeping and Management

By DANA & SAUNDERS

Rock Drilling

By DANA & TRIMBLE

The Trackman's Helper

HANDBOOK
OF
CONSTRUCTION EQUIPMENT

ITS COST AND USE

BY

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PREFACE

This book is presented in lieu of a new edition of the "Handbook of Construction Plant" which was published in 1914. Three paragraphs in the preface of that book outlined the plan of the work in the following terms:

"My principal reason for thinking that these notes would be useful to others is that I found them all but indispensable in my own practice, and not available in other form. My justification for the alphabetical method of classification is that this scheme admits of more rapid service on my desk than any other and I have attempted to supplement this arrangement by a very full index. For encouragement in this plan of procedure I am indebted to many of my engineering friends, who have aided by suggestions and useful criticisms.

"Finally, the keynote of the book has been practical utility to the man who has to buy, sell or use construction plant, or who needs to know what can be done with it. The existing facts in the shortest time on the reader's part, rather than interesting theory and clever comparisons have been kept most in mind. Because of this, a large wealth of material that would probably be of intense interest to the economist and the engineering student has been put aside for publication some time later if it seem desirable, but for which there is no space in this volume, which has grown to just double the size originally planned for it.

"A more general idea of the scope of the work, its field and its limitations may be found in the introductory chapter which follows the preface."

The trend of evolution in construction equipment is toward simplification in the design of each individual machine, and a more specific adaptation of such design to special uses. Consequently, the number of types of equipment is growing year by year, and each type, for its particular use, is more efficient than its predecessor. Wherefore, it behooves anyone having to do with construction equipment to be up-to-date in knowledge of what is available in the line of equipment, what it costs, and how to use it.

The prices have been revised as of 1920. A considerable amount of the old material which experience in estimating has shown to be of less than the average utility has been dropped from the book altogether, and about twice as much material as made up the old

book has been added to make the "Handbook of Construction Equipment" about three times as large in content, while only slightly more bulky in volume, than the "Handbook of Construction Plant."

The reader is very particularly referred to the introductory chapter which should be read by every engineer and contractor who buys the book, because in this chapter have been carefully brought together a number of hints and suggestions as to the use of the material for the purposes of the estimator. In a book such as this, containing a great many prices, the question is continually being asked: "Are the prices up to date; and, if not, what factors should be applied to make them so?" The data of this book are so fully given that the reader can readily make the necessary adjustments to fit the conditions of his locality and time if he will study carefully this chapter, entitled: "General Principles Applying to Equipment." Errors in estimating are generally due to one or more, usually more, of the following causes, viz: —

(1) Failure to visualize the conditions of the work.
(2) Failure to correctly gauge the trend of prices.
(3) The inadvertent omission of items because of incomplete lists.
(4) Alterations in design after the estimate has been made, under the assumption that the estimate provides enough leeway to cover them.
(5) Blunders in computation.
(6) Chance or accident, which cannot be altogether provided against by insurance.
(7) Erroneous information as to conditions, such as the working capacity of equipment.
(8) Bias, or the unconscious leaning due to an effort to make the estimate come to a certain figure.

It is believed that if the general principles of the chapter referred to be kept in mind the present volume, with its larger scope, will be more effective even than its predecessor in helping to remove the difficulties suggested by the above list of causes. If this be accomplished the author's hopes will be more than satisfied.

My sincerest acknowledgements are due to Mr. J. G. Breaznell of the Construction Service Company for his painstaking and most excellent work in checking over prices, reducing them to a 1920 basis, and in gathering together a vast quantity of this material.

RICHARD T. DAN/

15 William Street, New York, N. Y.

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HANDBOOK OF CONSTRUCTION EQUIPMENT

GENERAL PRINCIPLES APPLYING TO EQUIPMENT

At the time of this book going to press there is a labor shortage in the United States, and the rates of wages are higher than they have ever been before. Consequently, there is a great deal of construction work which cannot be done at all except by the extensive use of equipment, and there is other work for which capital is not obtainable unless it can be shown that new methods based on the use of equipment in place of labor will result in lower unit costs than can be hoped for by the old methods under present conditions, and that we are truly living in an epoch of manufactured power has been clearly noted in the little book, "The New Epoch," by the great George S Morison.

As a transformer of energy into useful work man is about the least economical machine in the world Working at top speed he can average in a working day not more than about 1/18th of one mechanical h.p. Compare this with the rate for electrical power in any civilized community and it is at once apparent what an overwhelming advantage is derived economically by reducing the employment of human energy to the absolute minimum consistent with due coordination on the work This means the substitution of equipment in place of human labor wherever it is possible to do so. Moreover, a h.p developed mechanically is very much cheaper than a h.p. derived from teams and guided by drivers. Therefore, wherever the same work can be done by machines that would otherwise be performed by horses the former is economically perferable.

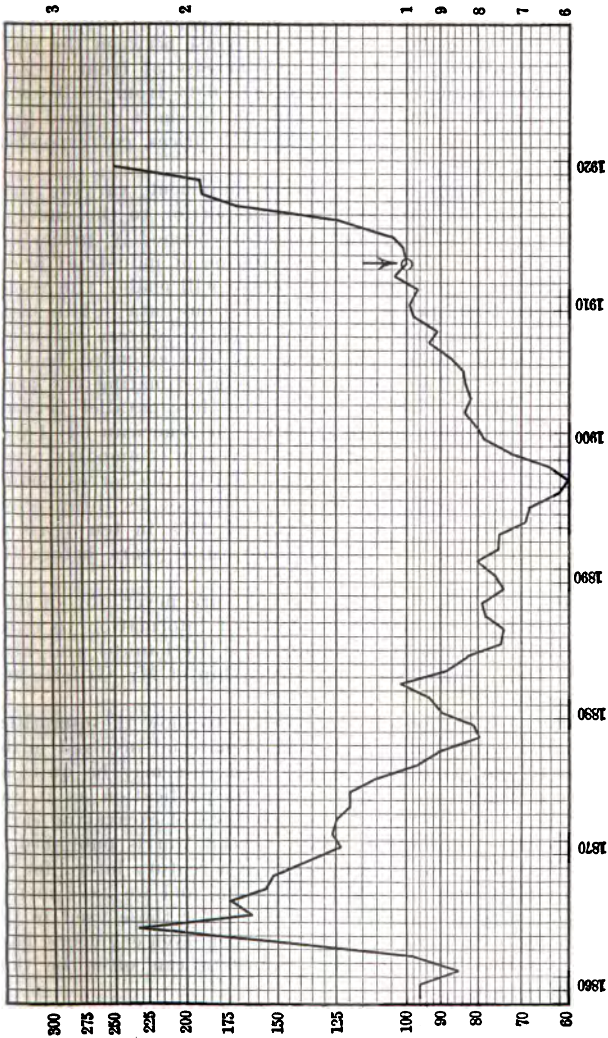
It is necessary, then, to know where and when equipment can be substituted for flesh and blood, what kind of equipment is available, and two cost factors,— first, how much of an investment is necessary, and second, how much the work of equipment, itself, would cost: in other words, how much capital is needed and what would be the unit cost through the use of the equipment, purchased or rented as the case may be.

The prices of equipment and the cost of labor have varied more within the last four years than at any other time since 1864 and, consequently, data of cost of plant, or cost of operating it, at any time within the five year period must be considered in connection with the dates at which the data were obtained. Commodity prices between 1908 and 1915, although showing a slightly rising tendency, were fairly stable, but from 1915 to 1918 average prices of commodities increased from 25% to 35% per year. In order, therefore, to make the most effective use of the data in this book, it is necessary to have a statement in convenient form of the trend of commodity prices, which is given herewith in the diagram, Fig. 1.

The index prices are those derived from two sources: (1) From 1859 to 1889, the index prices are those given in Senate Report No. 1394 on "Wholesale Prices, Wages and Transportation," by Nelson W. Aldrich, March 3, 1893. The weighted average index prices there given are multiplied by 0.9 to reduce them to the same base as the index prices, of the U. S. Bureau of Labor, the latter index prices being those from 1890 to 1919, using the year 1913 as 100. The Aldrich report index prices are based on the wholesale prices of 223 commodities, weighted in proportion to family budget expenses. The Bureau of Labor index prices are based on the wholesale prices of 192 commodities in 1890, as given in Bulletin No. 173, and in the Monthly Labor Review, December, 1919, and January, 1920.

If the index prices given in Dun's (Mercantile Agency) Review are multiplied by 0.83 they will be reduced to the same base (the year 1913 being taken at 100) as that used in this table. Dun's index prices are the weighted average of 300 wholesale quotations on commodities (the weighing being in proportion to annual production). The quotations are taken for the first day of each month, and the resulting index prices for each of the 12 months are added together and divided by 12 to give the figures that appear in the last column of this table for every year from 1898 to 1919, inclusive; but prior to 1898 Dun gives index prices only for Jan. 1 and July 1, of each year. The numbers given in the last column of this table from 1860 to 1897, inclusive, are the index prices on July 1. Index prices on July 1 are ordinarily quite close to the average for the entire year. In not a single year since 1898 have Dun's index prices for July 1 differed by more than 4% from the average for the 12 months; but for the years 1863 to 1869, it seems evident that Dun's index prices for July 1 (which are those given in the table) are not typical of the entire year.

This diagram is plotted on semi-logarithmic paper on which



Relative Index Prices (Wholesale) of Commodities in U.S.A. - Dun's
Based on Year 1913
Fig. 1.

similar percentages of variation show up equally to the eye regardless of the location of the curve on the paper. Thus, for instance, the Dun curve shows a relative increase between the years 1897 and 1908 of 65% or an absolute increase of from 60% to 99%. A corresponding relative increase of 65% from 1913 would be shown by equal vertical measurement on the chart upward from the 100% line indicating 165% of the 1913 prices, corresponding approximately to the prices of 1917.

Of course, the prices of construction equipment, varying from year to year, will not vary exactly in proportion to the curve of commodity prices but since the weighted commodity prices are generally accepted as the best basic criterion of industrial prices generally, the intelligent use of this curve will enable the reader to make the most satisfactory use of the various data in this book, which have been compiled from a multitude of sources extending over a great many years. The curve has been extended back to 1860 and may be used to good advantage in estimating the probable trend of future prices in view of the close parallel between the action of those prices before and after the American Civil War and the great World War. Note that the rise in commodity prices from 1915 has been almost exactly parallel to the corresponding rise from 1862, and note, also, that the curve of declining prices after 1864 has been at about the rate of 23% in ten years as compared with a rise of 23% in about three years before the peak.

Cost data, as distinct from price lists, are never out of date provided they are accompanied by sufficient information to interpret the conditions. In the "Handbook of Mechanical and Electrical Cost Data" under the joint authorship of Mr. Gillette and myself we said:

"If a unit cost has been so analyzed as to show the quantities of each kind of labor and of each kind of material involved in the production of the given unit, such a unit cost may be quite as serviceable a generation or more after its publication as it was when first published Thus, the yardage costs of excavating earth with drag-scrapers and horses which Elwood Morris published in 1841 are applicable now, three-quarters of a century later; for we still use drag-scrapers for earth excavation, and we have merely to substitute present team and man wages for those used in the time of Morris. Curiously enough many men, even engineers, have failed to see that 'out of date' cost data can often be thus brought up to date.

"Rates of wages are frequently omitted in giving unit costs, but, if the date when the cost was incurred is given, it is usually possible to ascertain the wage rates that then prevailed. An ex-

perienced engineer often knows offhand the prevailing rates of wages that were paid in any part of the country at any given time. While it is true that wages of individual workmen often differ quite widely even in the same locality and at the same time, it should be remembered that this difference is usually consequent upon their individual differences in efficiency. Thus, when railway carpenters were paid $2 50 a day and contractors' carpenters were paid $3 00 in the same locality for the same class of work, the carpenters working for a contractor did fully 20% more work daily. Hence the unit cost of carpenter work did not differ materially even where the wage differed 20%.

"The labor cost of installing a machine is very often estimated as a percentage of the cost of the machine. Suppose, for example, a given machine was installed 20 years ago at a labor cost that was 10% of the cost of the machine. If the general level of wages and machine prices has risen 75% since that time, then the ratio of labor cost of installation to machine cost would still remain 10%; and the labor cost data of 20 years ago would remain applicable today if applied as a percentage to the present cost of the given machine.

"The labor cost of installing equipment is frequently estimated in dollars per ton of weight. Although the weight of a machine of given size and type is seldom given in an article containing costs of machinery installation, the weight is usually ascertainable from tables such as are given in this book; and then a published labor cost of installation of a machine may be converted into a cost per ton. Old installation costs per ton may be brought up to date by making proper allowance for the rise in wages.

"In making tables that give the prices of machines and equipment of different types and sizes we have given also the weights. It is therefore possible to deduce from our tables the price per lb. of each size and type of plant-unit. Our prices were normal prices at the factories in 1913 and 1914, prior to the world war. It might seem at first sight that these tabular prices will be valueless at least until the war is ended and normal economic conditions are restored. Yet a little consideration of the matter will show that our tables of equipment prices may be used effectively now. To illustrate, suppose it is desired to estimate the present price of electric transformers of different sizes. Secure either the price actually paid recently for a given transformer, or secure a quotation, then divide this price by the price given in our table, and thus establish the factor by which to multiply other prices in the same table to get present prices. This procedure will save time and trouble. Moreover, it will be found much easier to secure a few quotations from manufacturers or their agents than to

secure as many as may be needed for an approximate appraisal or a preliminary estimate of cost of a proposed plant unit."

Much trouble has been caused for contractors and many engineers by a failure to appreciate in its true importance the matter of depreciation of equipment. The subject is somewhat intricate and cannot be adequately discussed in a page or two whereas inadequate discussion of it is likely to be misleading. The reader is, therefore, referred to pages 82 to 144, covering a full discussion of depreciation with very elaborate tables of the estimated lives of plant units, in the "Handbook of Mechanical and Electrical Cost Data" above referred to.

The problem of how to carry out a given plan of construction at the lowest cost is year by year becoming more complex, and it is becoming more and more necessary to apply to it scientific methods in order to meet the growing competition between various men, methods, and machines. The contractor of long experience who applies to his work, even in its simplest operations such as moving earth by scrapers, the methods that he knows absolutely were the best ten years ago, is competing, whether he knows it or not, with men who have developed up-to-date methods that are very likely to be twenty, thirty, or even forty per cent more efficacious or economical than the best old ones.

It is of vast importance to know the relative costs of different methods, some of the reasons for which it seems worth while to outline here. Before bidding on new work, it is generally not difficult to find out what methods the other bidders are accustomed to, and, by making independent estimates based on the probable methods for the most dangerous competitor, to reach a figure that is something better than a mere guess at what his bid may be. Of course, it must be distinctly understood that this is not an attempt to eliminate human nature from the contracting business. The "most dangerous competitor" may suddenly change his methods and upset a lot of calculations, and whether he will do this or not is just as much a matter for psychologic study as what sort of hand he is drawing to when he takes one card. Nevertheless the man who knows his competitor's usual methods, and knows the relative efficiency of those methods as compared with his own, is in a position to bid much more intelligently than he otherwise could. With the increasing disuse of old methods it is necessary to know the value of the new ones in order to know whether it will pay to change from old equipment to new, and how much (if anything) the change may be expected to save; and it is vastly important to know what is the very best method for the work to be done. Even if a contract can be carried out at a handsome profit by the second best or third best method,

the man is a fool who would hesitate to discover and apply the first best, thus converting a handsome profit into a still handsomer one. When, moreover, a loss is being faced, it is almost always due, according to my experience, to the fact that the wrong methods were in use, rather than that the contract had been taken at "impossible figures." In such a situation the first and most necessary move is to ascertain the very best method and apply it immediately; and to assist the contractor and the engineer in the selection and application of the best method in the least time is the main object of this volume, which is devoted to Field Equipment.

It is a fact of common experience that if we want, or think that we may want, a piece of equipment for certain work, we can have a large amount of free literature upon the subject, backed up by the extensive experience and earnest enthusiasm of the salesmen of equipment houses. Such information is not always reliable and it is generally confusing. Moreover, before it can be applied to the work in hand it must be sorted, collated, studied and verified, a process requiring a ruinous amount of time for every investigation. This book attempts to save the estimator and contractor a large part of this time, which is ordinarily lost. The author has never sold any kind of equipment on commission and has never received a commission of any kind for recommending the adoption of any machine or tools for any purpose, and has no interest whatever in any statement contained in this book except to see that it correctly represents the economic facts in a useful and convenient way. Although it has been carefully checked for errors, it is possible, of course, that mistakes may have escaped notice. If any such should be noted, a memorandum, mentioning page-number and line would be greatly appreciated.

The main features of equipment which bear upon economic operation are as follows:

C Cost, ready to commence work.
Q Capacity, minimum, standard and maximum.
E Operating expense, including depreciation and repairs.
A Adaptability to the conditions governing the work.

No effort has been spared in preparing this volume to put the information into such form as to make it available, with the minimum of time and trouble, and it is believed that with the aid of the information contained in these pages an intelligent estimator of practical experience can determine within reasonable limits the figures for each of the above features. Prices vary from year to year, and terms of sale change with the conditions; but within a limit too small to affect materially an estimate of

unit cost for plant performance, I believe the facts here given may be safely used. For making appraisal of a plant to be sold, if these figures be used they should of course be checked by actual bids from the manufacturers or dealers to the appraiser. In nearly every instance the prices here given represent bona fide quotations made to the author, but since the book is not written to advertise anyone no names are given.

Except where otherwise expressly stated the prices are f. o. b. the manufacturer's works.

(C) The cost, ready to commence work, includes
  (p) the purchase price, the
  (t) cost of transportation, and the
  (a) preparatory cost, including unloading, erecting and getting into working position.

When possible the shipping weights have been included here, and the freight rate may be obtained from the nearest railroad agent, usually on the telephone. Data on the cost of erecting and installing machinery are not very plentiful. I have included them wherever possible from the available information.

(Q) The capacity of equipment is a very elusive quantity. That of a wagon, ship, bucket or scraper is usually listed by the manufacturer as the "water measure" capacity and must be corrected to obtain the "place measure" capacity. The capacity of a steam shovel in theory is the "water measure" of the bucket multiplied by the rated number of swings per unit of time; in practice it is likely to average from 20% to 70% of this, with the odds on the lower figure. Therefore the capacity figures must be taken as purely relative for the purpose of defining the size or type of equipment mentioned. A good many elements enter into this, not the least of which is often the skill of the operator. A steam shovel, in particular, is dependent for its capacity upon the skill of the runner and the manner in which the runner and craneman work together. The character and condition of the material that is handled may greatly affect the performance, so that capacity under ideal conditions (which is the manufacturer's assumption when rating his machines) is simply the maximum, and is rarely to be equaled in working practice. Moreover, the capacity of such a machine as a steam shovel is limited by that of the cars into which it is loading, and is affected by the necessity of "moving up," and of changing trains, etc.

(E) The cost of operating a machine depends a good deal on the skill of the operator, as well as on the layout of the work, weather conditions, etc. In estimating this quantity, there should be included the incidental and necessary costs without which it

cannot work to advantage. The cost of operating a hoisting engine, for example, includes that of coal "on the platform," which may include the cost of hauling coal from a delivery point, and should include the cost of coaling at night, watchman's time, etc. The operating cost and operating capacity are reciprocally dependent on each other.

(A) The adaptability of a particular machine to the conditions governing its work is often, if not always, the most important feature to be considered in its selection, since on this feature its practical efficiency for the work in hand largely depends. Adaptability is affected by the peculiarities of the work on which it is to be employed as well as those of the machine itself, and for a proper judgment as to its value an intimate knowledge of the machine and a thorough knowledge of the conditions under which it is to work are necessary. Unfortunately the working conditions are not always ascertainable with sufficient exactness to be sure of selecting the most suitable plant, and, more unfortunately, reliable information about new equipment is scarce. Salesmen, while probably no worse than the rest of mankind, are always biased by their personal interest in the product that they handle, and they cannot be expected to give due weight to the faults of their own machines or the virtues of those sold by their competitors, and are poor advisers in consequence. Theoretically, a way to avoid this disadvantage would be to call in rival salesmen and let them talk out the whole subject in the presence of each other. The writer tried this plan just once, at the request of a client, and it was a howling failure. Advertising statements, while honestly meant, are apt to be outrageously deceptive. As an instance of this, the following was cut out of one of the technical journals:

"DUMP WAGON COSTS

"Eight men can shovel one cubic yard of loose sandy loam into a dump wagon in 3 minutes, therefore, in a 10 hour day these 8 men could load 200 cubic yards of material. At $1.50 per day, 8 men cost $12.00; therefore, the labor cost alone on 200 yards would be 6 cts. per cubic yard.

"OUR COSTS

"This cubic yard machine is loaded in ¼ minute; therefore, in a 10-hour day one man on this machine can load 2,400 cubic yards of material, or 12 times as much as 8 of your competitors' men can shovel in a 10-hour day.

"On the above basis we figure the two teams and their drivers, and even then taking this cost at $10.00, the cost per cubic yard would be four mills.

"There are a number of items and incidentals yet to be added to both of these costs but the ratio of cost is as 1 to 21 in favor of this scraper."

This is cost analysis gone mad with a vengeance, yet the man who wrote it in all probability thought that he was highly conservative. A great many manufacturers use special care that the

statements in their trade literature shall be undeniably on the safe side on account of the very bad moral effect of an exaggeration. One of the large manufacturers of electrical machinery has been known to permit salesmen to state as the working efficiency of certain machines a percentage of the results shown by mechanical tests, on the ground that a disappointed and disgusted customer is the worst advertisement possible. Notwithstanding this fact, there are many machines that would be much more generally used did contractors feel confidence in the statements regarding them. The old and tried machine that is not especially well adapted to the work in hand is thus often used for lack of reliable information about the new and unknown one.

No book can tell a contractor automatically what equipment is the best for his use, but it is possible to put him in possession of vastly more information than has heretofore been available, and this has been attempted in the present volume.

The object of this book being primarily to furnish the information needed by contractors, and the material having become rather voluminous, it was thought advisable to leave out a great many items which might be useful to a very few contractors, but which would not be generally employed by the vast majority of them. The author will appreciate hearing from contractors who would like to find more material than obtained in the book, with a view to finding out the exact demand for extra matter, and will endeavor to insert such additional material in future editions.

A most important point to which attention is called is that all the illustrations in this volume are for the purpose of illustrating types of machines of which costs and performances are given. No quotation or price mentioned in these pages is to be taken as referring exclusively to any one machine illustrated or to the production of any one manufacturer. The prices are frequently averages of several quotations, while the illustration that goes with this price is that of a standard piece of equipment.

SECTION 1

AIR COMPRESSORS

These machines are for the purpose of putting power into proper form for convenient and economical transmission. Many of the operations that formerly were done only by hand are now being accomplished by machinery and machine tools driven by compressed air or its substitute, compressed steam. Under many circumstances a drill can operate by steam as well as by air, while for the hand tools, such as riveters, stone cutters, etc., the use of steam is not convenient because of its high temperature and sometimes because of the dense white cloud of condensing steam which is opaque and wet. In general, air is never at a disadvantage as compared with steam in convenience of working; and where they are equally convenient the ruling economic feature is the distance to which the power must be transmitted. A boiler is less expensive than a boiler and compressor of the same power; hence for short distances the steam power is more economical, other conditions being equal. As the distance of transmission increases, the relative economy of the steam transmission decreases, on account of heat losses, and there is, therefore, a point at which the extra economy of the air transmission equals the extra cost of the compressor. For greater distances than this the air transmission is economic; below it direct steam is the less costly. The actual position of this critical point for each set of conditions depends on the conditions themselves and can be worked out when they are all determined. It should be remembered, when considering such a problem, that it is quite possible to carry steam for half a mile in well lagged pipe with inconsiderable heat losses.

The chief peculiarity of air compression for these purposes is that, as the air becomes compressed, its temperature rises. It may then be cooled at the place of compression by artificial means, or it may be admitted to the transmission pipes without first being cooled. In the latter case it becomes cooled more or less in transit, necessarily losing some of its pressure by the act of cooling, with a consequent loss of efficiency. For large installations, therefore, it is customary to do the cooling in the engine by a water jacket, or water jets.

A cubic foot of "free" air, at normal atmospheric pressure of 14.7 lb. per square inch and initial temperature of 60° F., will have a temperature of about 225° F. and pressure of 2.64 atmospheres when compressed to one-half its original volume if there be no escape of the heat which is necessarily generated by the increase of pressure. This is "adiabatic" compression, or compression without loss of heat. If by a cooling arrangement the generated heat could all be removed as fast as generated, so that the temperature should remain constant, then the final pressure would be two atmospheres for the above example, and the compression would be "isothermal." In actual practice some heat is lost through the cylinders, so that neither the adiabatic nor isothermal curves represent accurately the facts.

If V represents final volume,
V' represents initial volume,
P represents final pressure,
P' represents initial pressure.

Then in general,

$$(1) \qquad \frac{P}{P'} = \left(\frac{V}{V'} \right)^{n}$$

(2) For isothermal compression, $n = 1$
(3) For adiabatic compression, $n = 1.4$

For commercial machinery the exponent will be somewhere between these figures, depending upon the efficiency of the machine and the amount of cooling that is introduced into it. These three simple formulas combine the theoretical facts. The diagram, Fig. 2, giving in graphic form the adiabatic curves for temperature, pressure and volume will enable the approximate temperature to be obtained without tedious calculation.

Chart for Finding Air Consumption of Drills. The following notes are from an article by Robert S. Lewis in the *Eng. and Min. Journal:*

The chart Fig. 3 is a modification of the one appearing in "Rock Drilling," by Dana and Saunders, with the addition of data for hammer drills and basing the diagram on an air pressure of 90 lb. per sq. in. at the drill instead of 75 lb., to conform more nearly with the requirements of modern practice.

The inclined lines are based on a sea level datum and 90 lb. pressure per sq. in. at the drill. This gives a factor of 1; for any other altitude or pressure at drill, the factor is found at the left margin, passing there from the intersection of the inclined line of the given altitude with a vertical through the given pressure.

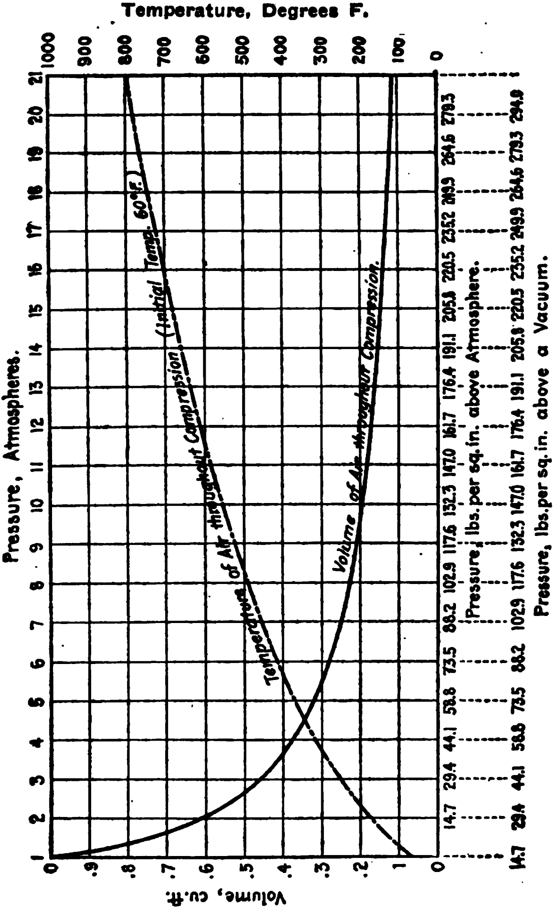


Fig. 2.

The average consumption of air for both piston and hammer drills is given in the table of Air Consumption of Rock Drills.

Hammer drills vary so in air consumption that only general figures can be given. Catalogs from drill manufacturers will give the consumption for any particular drill and generally at 90 lb. pressure at sea level. By means of the chart the consumption for other conditions can be quickly found.

Table of Air Consumption of Rock Drills, Cu. Ft. per Min.

90 lb. at Sea Level. Piston Drills.

Drills, in.	2	2¼	2½	2⅝	2¾	3	3⅛	3¼	3⅝	4¼	5
Cu. ft. p. min.	68	87	92	98	118	125	129	136	161	210	250

90 lb. at Sea Level. Hammer Drills.

	Stopers	Drifters	Sinkers	Block Holers	Hitch Cutters
Cu. ft. p. min.	48–55–58	40–60	38–60	25–30	15–25

In case more than one drill is used, the factor by which to multiply the air consumption of one drill to determine the consumption of a number is to be taken from the following table.

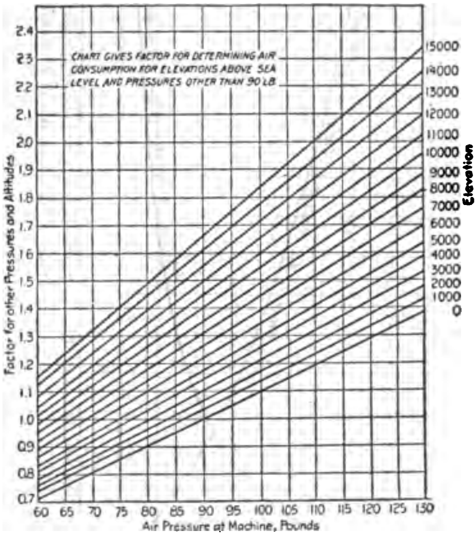


Fig. 3. Chart giving Factor for Determining Air Consumption for Elevations above Sea Level and Pressures other than 90 lb.

This is based on manufacturers' statements. When a number are working they are seldom all running at the same time. This table covers the requirements of from one to sixty drills.

Air Consumption for More Than One Drill

No. of Drills	1	2	3	4	5	6	7	8	9	10
Factor	1.0	1.8	2.7	3.4	4.1	4.8	5.5	6.1	6.7	7.3
No. of Drills	11	12	15	20	25	30	35	40	50	60
Factor	7.8	8.4	10.3	12.8	15.1	17.3	19.7	22.0	26.5	30.5

Compressed Air Plant for Contracting. Mr. W. L. Saunders to whom, probably, the compressed air industry owes more than to any other living man, published the following notes in *Engineering and Contracting*, Mar. 19, 1919. The character of the work is an important feature in the determining of the size and the selecting of the type of air compressor plant; for instance, such work as tunnel driving, aqueduct construction, canal excavation, etc., might well utilize a number of semi-permanent air compressor installations, as such work usually extends over a considerable period of time. On the other hand, such work as road building, open cut excavation, trench digging, structural work, etc., could more profitably employ portable air compressor plants which move with the work.

In the case of semi-permanent installations the requirements may call for the installation of both high pressure and low pressure units, the former for purposes of operating rock excavating machinery, pneumatic placing of concrete, the operation of water pumps, hoisting engines, pneumatic riveters, and the like.

The availability of motive power will be a deciding feature in the selection of the type of air compressor.

In earlier practice it was customary to operate rock excavating machinery by steam, utilizing the boiler horse power direct, and thereby eliminating one item in the initial cost of equipment. On the other hand, the development of efficient steam operated air compressors and greatly improved compressed air operated rock drills caused the contractor to realize that he could effect more efficient and economical operation by installing an air compressor, than he could by adhering to the now admittedly obsolete practice. The greater loss experienced in the transmission of steam over long distances, as compared with that of air, and the greater consumption of boiler horse power in the rock excavating machine per unit of work, as compared with compressed air drills, more than compensated for the additional initial outlay.

For portable compressed air plants, the choice of motive power falls naturally to gasoline driven types, due to comparative lightness of the equipment, the simplicity of operation and the ease with which satisfactory operating labor may be secured. On city street work it is sometimes advisable to use a motor driven portable unit, securing electric power from trolley lines or commercial power circuits. In building construction the semi-portable skid-mounted motor driven units are customarily employed.

With semi-permanent installations it becomes necessary to provide suitable housing and foundations of semi-permanent character. The question of housing is a simple one; the only

precaution required is the protection of the plant from the elements. With work of long duration, it is advisable to install a foundation of mass concrete or stone masonry structure. This is particularly true of large machines. Machines of small and moderate capacity customarily employed on short time jobs give satisfactory service bolted to skid foundations, firmly anchored.

On penalty jobs, or in such work as pneumatic caisson sinking or shield tunneling, where the lives of the workmen are dependent on the absolute uninterruption of the air supply, it is imperative to install duplicate units, so as to insure against failure of the power supplied.

The radius of distribution of compressed air from a central station is practically without limit.

Transmission lines will vary from 2 to 6 in. in diameter, depending upon the size of the installation and the distance of transmission. Suitable control valves should be provided at the power house, as well as the points of outlet.

In pneumatic caisson work an after-cooler forms an essential part of the air compressor equipment, it being utilized to remove the heat of compression and deliver the air to the air locks at normal temperature.

In the operation of pneumatic tools of various kinds, particularly in cold weather, some trouble may be experienced from freezing, and under such circumstances it becomes advisable to install some form of air reheater, which not only eliminates this trouble but increases the power delivered by the air compressing plant.

A properly designed air transmission line should include the installation of moisture traps at convenient intervals for the removal of the moisture which the air contains and which is deposited in the transmission line.

Modern air compressors have reached such a high state of refinement that aside from an occasional inspection to insure tightness of stuffing boxes, absence of leakage in the transmission line, and the proper functioning of the lubricating devices they require very little attention on the part of the operator. Most machines have their driving parts automatically splash-lubricated with force feed pumps supplying the cylinders. Air compressors for permanent or semi-permanent installation vary in size from 50 to 10,000 cu. ft. of free air per minute, pressure ranging from 15 to 125 lb. Portable air compressor plants range from 50 to 500 cu. ft. free air per minute at similar pressures.

Types of Compressors. Compressors may be divided into two general classes. The first classification divides them into the

straight-line compressor in which the steam and air cylinders are arranged in a straight line and the power is applied through a single long piston rod connecting all pistons; and the duplex compressor which consists of two compressors set side by side, each made up of a steam and an air cylinder connected to a crank shaft carrying a single balance wheel. The cranks of the two sections are set at a 90° angle to each other with the object of producing no dead center and to enable the machine to operate at very low speeds.

The straight line machine is usually of lower cost, requires lighter foundation, occupies less room than the duplex, is more reliable in the hands of an average engineer and is a machine for every day service in moderate capacity. The duplex has more uniform operation, higher efficiency and greater steam economy. Another advantage is that in case of accident one side of the machine may remain uninjured and can be run in an emergency.

The second general classification divides them into steam driven and power driven compressors. In the former the steam cylinder is an integral part of the machine. In the latter the compressor is operated by power outside of the machine and may be driven by belts, ropes, chains, gears, or a direct shaft connection. Of these the belt driven is the most common and the direct shaft is used only with electric motors or water wheels. Compressors may be classed also as vertical and horizontal. The vertical type is advantageous where space is limited, as the machine is small, and is commonly restricted to the power driven class. The horizontal type is generally considered the better. Another classification is that of the single stage or compound stage. This has to do with the degree of compression to which the air must be subjected.

Locomotive Compressor. The simplest of air compressors is the standard locomotive pump used for air brakes. This machine is of the straight line type and was originally designed for locomotive air brake use, but has since been applied to over one hundred different kinds of service, such as small pneumatic tool operation, cleaning metal surfaces, sand-blast outfits, in sewage ejectors, for pumping and conveying liquids.

This compressor is made in two types, the single cylinder and cross-compound. A 35 cu. ft. per min. displacement at 100 lb. pressure, single cylinder machine, weighs approximately 550 lb. and is priced at $130. The 50 cu. ft. size weighs 650 lb. and costs $160. The 70 cu. ft. size weighs about 1000 lb. for shipment and costs $235. The cross-compound type in the 150 cu. ft. size at 100 lb. pressure weighs about 1750 lb. for shipment

and costs $375. All the above prices are f.o.b. manufacturers' works.

This form of compressor requires no foundation (being bolted to a column or wall) nor accurate alignment of parts. The usual method of installing a water jacketed compressor of this type is

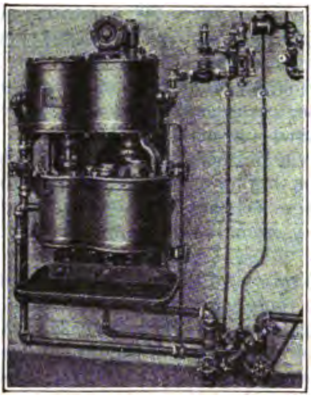


Fig. 4. Locomotive Compressor Cross-Compound Type.

shown in Fig. 5. If the conditions do not require a water jacket the water pipe connections and valve, and radiating discharge pipe may be omitted. The approximate prices of the chief elements are: Lubricator, $10.00; Governor, $21.00; Air gauge, $3.75; Main reservoir, $36.00; Drain cock, $1.50.

Single Stage Vertical Air Compressors

60–100 lb. press.

Rated capacity in cu. ft. per min.	Approximate shipping wt. in lbs.	Price f. o. b. factory
6	100	$ 45
10	160	60
25	370	100
50	700	180

Single Stage Vertical Compressors for belt drive are designed for either intermittent or continuous service where air is required in small quantities. When electric power is to be used these machines are equipped complete with motor, driving pulley, endless belt and short drive attachment; all mounted on a hardwood base, ready to set on foundation and not requiring

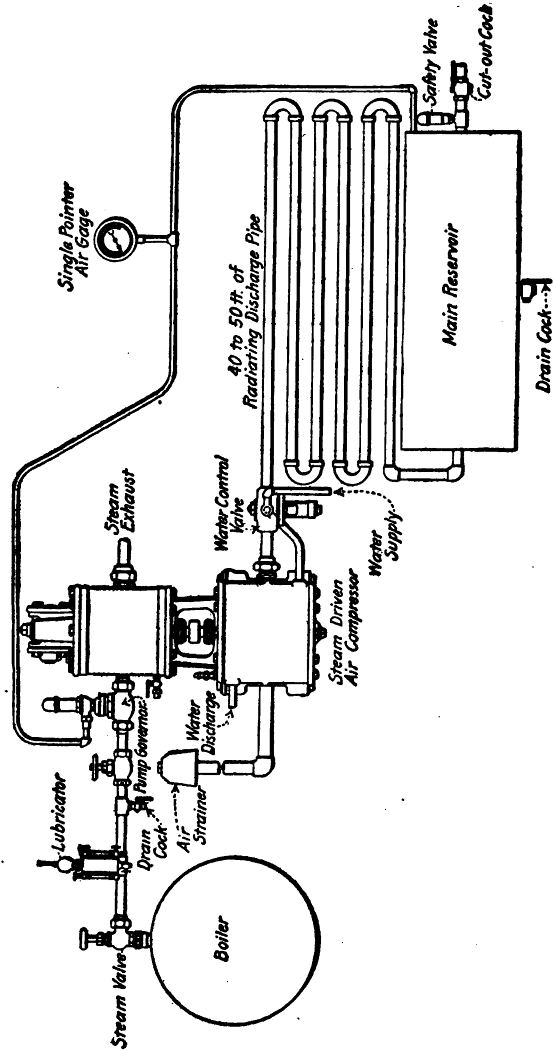


Fig. 5. Diagram of Installation of Steam Driven Air Compressor Plant.

any adjustments or aligning. Motors are furnished to order to suit power requirements.

Power Driven Single Stage Straight Line Air Compressors.

100–150 lb. pressure.

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
30	660	$ 330
50	1220	400
100	2300	600
150	3200	780
200	4100	960
300	5700	1300
350	6300	1450

Vertical Type Motor Driven Air Compressors are illustrated by Fig. 6. This type of compressor, 90 lb. per sq. in. pressure, costs as follows: In the 50 cu. ft. per min. size, the approximate shipping weight is 3500 lb., price $1550; the 100 cu. ft. size weighs about 5000 lb. for shipment and is priced at $2100; the

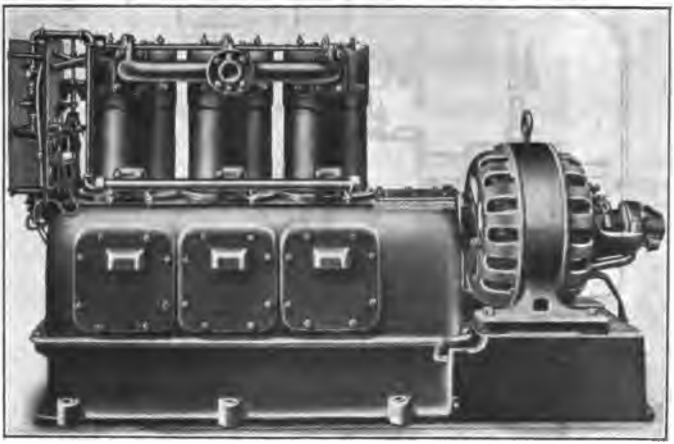


Fig. 6. 150 ft. Alternating Current Air Compressor with Combined Automatic Controlling Device.

150 cu. ft. size weighs about 7500 lb., price $2500; the 200 cu. ft. per min. size weighs 10,000 lb. for shipment and costs $2900. All the foregoing prices are f. o. b. factory for complete compressors fitted with D. C. motors for 220 volts and waterjacketed.

This type of compressor may also be had in capacities of from

40 to 450 cu. ft. per min. at pressures of from 30 to 150 lb. per sq. in.

Steam Driven Simple Straight Line Air Compressors

80–125 lb. pressure

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
75	2500	$ 940
100	3100	1000
150	4100	1200
200	50[illegible]	1420
250	5900	1650
300	6300	1850
350	7400	2030
400	8200	2200
500	9400	2600

10–50 lb. pressure

150	2750	1100
300	4700	1620
500	7000	2200
750	9600	2750
1000	12000	3300

Steam Driven Two Stage Air Compressor

60–100 lb. pressure

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
200	6200	$1900
300	8200	2350
400	10000	2700
500	12000	3100
600	14000	3400
800	18000	4200
1000	23000	4800
1200	30000	5700

Power Driven Two Stage Air Compressors

80–100 lb. pressure

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
200	5800	$1400
300	7200	1750
400	9000	2100
500	11000	2400
600	12500	2700
800	16000	3200
1000	20000	3800
1200	23500	4300
1400	27000	4800

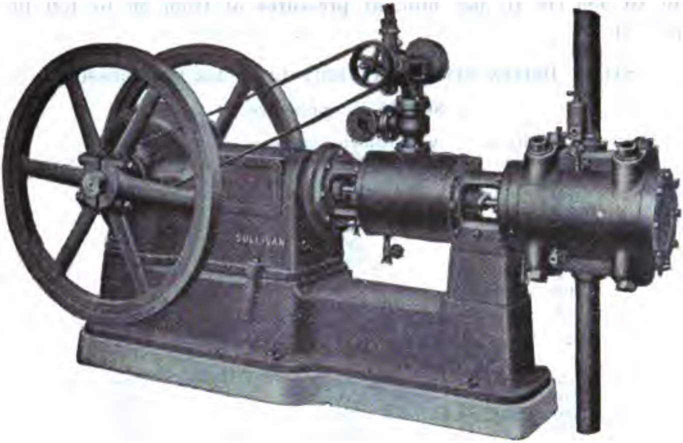


Fig. 7. Steam Driven Straight Line Air Compressor.

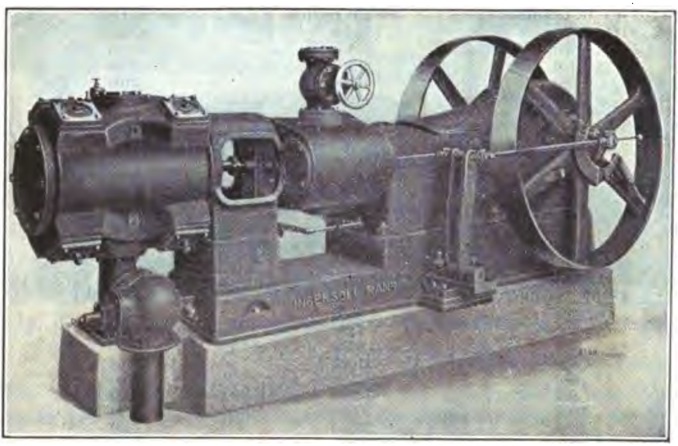


Fig. 8. Steam Driven Straight Line Air Compressor.

Fig. 9. Angle Compound 2-Stage Power Driven Air Compressor.

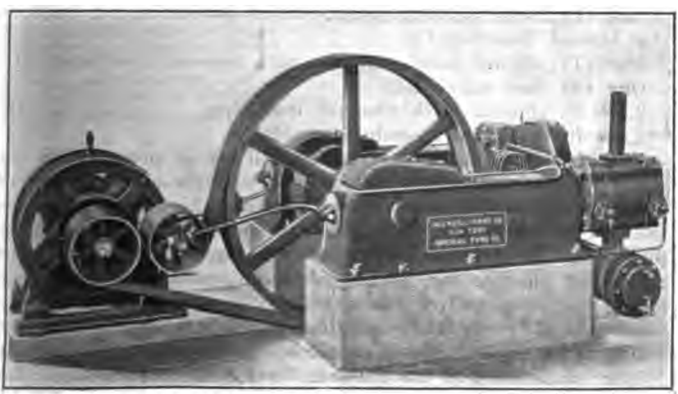


Fig. 10. 2-Stage Power Driven Air Compressor.

COST OF COMPRESSOR INSTALLATION

An air compressor, electric generating, and pumping outfit was installed about 1912 for the Water Board of the City of New York at Cornwall Landing on the Hudson River, about 2,000 ft. south of the West Shore Railway Station. This plant was used to supply air for drills, pumps, and general shaft and tunnel work, in driving the siphon under the Hudson at Storm King Mountain.

Compressor Equipment Installed. Two (2) $\frac{16}{28} \times \frac{25\frac{1}{4}}{16\frac{1}{4}} \times 16$ Class "HH-3" cross compound steam driven air compressors, having a piston displacement each of 1392 cu. ft. designed to operate condensing; air pressure 100 to 110 lbs; steam pressure 150 lb.

One (1) 48″ improved type of vertical aftercooler.

One (1) 54″ dia. by 12′ vertical air receiver.

Boiler Equipment and Pumps, etc. Three (3) 130 hp. Sterling boilers.

Two (2) 6 x 4 x 6 outside packed boiler feed pumps built by the Buffalo Steam Pump Co.

Two (2) 6 x 5¾ x 6 piston type tank pumps built by the Buffalo Steam Pump Co.

One (1) 10 x 18 x 10 independent jet type condenser built by the Buffalo Steam Pump Co.

One (1) 400 hp. enclosed Berriman type feed water heater built by the F. L. Patterson Co.

One (1) 20 K. W. Kerr steam turbine generating set built by the Atwood Reardick Co.

One (1) station panel complete with necessary switches, etc.

One (1) feed water tank.

2,500 ft. of 6-in. black wrought iron pipe.

2,500 ft. of 1½-in. 2 conductor cable.

The above equipment was installed on rented property on the Hudson River and immediately adjacent to the right of way of the West Shore Railroad. Cost including this equipment plus the cost of the railroad siding, actual building and foundations, piping in power house, boiler setting, together with all labor and other charges for putting this equipment into operation, laying the air pipe from the plant to the shaft, some 2,400 ft. distant, and electrical connections between shaft and power house, and adequate well to obtain boiler feed water and making proper connections to the Hudson River with strainer, etc., for condensing and circulating purposes, approximately $35,000.00, which includes the following costs: Compressors, aftercooler

and receiver, approximately $13,500. Balance of equipment, consisting of boilers, pumps, generator set, water tank, pipe and electric conductor, etc., about $10,000. Railroad siding, building and foundations, piping in power house, boiler settings, well, erecting stacks, labor, superintendence, charges for placing plant in operation, rental, lease for railroad siding, and incidentals, $11,500.00.

Formulae of Costs of Air Compressors. Mr. A. A. Potter in *Power*, Dec. 30, 1913, derived the formulae in the following table for the costs of air compressors, by tabulating and plotting the net prices received from several different manufacturers. The prices are the net selling prices f. o. b. factory and do not include the cost of erection.

Type	Capacity up to cu. ft. per min.	Equation of cost in dollars
Single cylinder, belt driven	4000	52 + 1.95 × cu. ft.
Duplex, belt driven	850	316 + 1.675 × cu. ft.
Compound, belt driven	550	3.1 × cu. ft.
Single cylinder, steam driven	350	231 + 2.32 × cu. ft.
Duplex, steam driven	600	460 + 2.55 × cu. ft.
Compound, steam driven	500	71.25 + 4.025 × cu. ft.

The results obtained in the use of the above equations should be multiplied by 175% to bring them to 1920 prices.

COST OF MOTOR DRIVEN COMPRESSORS WITH AUXILIARIES AND THEIR INSTALLATION

	220V	220V	220V	600V	600V	600V
Piston displacement in cu. ft. per min.	15	25	50	50	15	25
Shipping weight in lb.	630	830	2050	1460	620	880
Net price compressor f. o. b. factory	$220	260	450	400	175	225
Net price governors and switch f. o. b. factory	40	40	40	20	20	20
Freight and drayage at $1.50	9	12	31	22	9	13
Est. cost of receiver, piping, etc.	40	40	40	40	40	40
Cost of installing	15	15	15	15	15	15
	$324	367	576	497	259	313

The above amounts should be doubled to equal 1920 prices.

Separator for Removing Water from Compressed Air. In connection with the operation of pneumatic tools any water which is in the compressed air supplied to them occupies valuable power space in the cylinders of the tools, thereby decreasing their efficiency and sooner or later resulting in damage, due to the constant internal hammering action of the water. The separator utilizes centrifugal force to remove the water from the air. As the air and water enter it they pass through a helical path formed about a central cylinder, resulting in a swirling motion of the entire mass. As water is several times heavier

than air it is thrown out of the curving air current, and against the walls of the separator, which it meets at an angle without any spatter or splash and slips smoothly along until it reaches the receiver space at the bottom. Here the motion is retarded by vanes in order to permit drainage of the accumulated water. The resulting separation is practically complete with very little pressure loss. The separator is made of close grained cast iron, suitable for a working pressure not in excess of 200 lb. per sq. in., is simple in construction, has no movable parts and will operate indefinitely with a minimum of attention.

In order that the separation may take place when the air is at its lowest temperature, it is desirable to install the separator as near as possible to the point at which the air is to be used. In the case of long air pipe lines out of doors, where there is a possibility of freezing, the separator should be placed in the line at a point just before the pipe leaves the heated building. To maintain the best operating conditions it is well to install a trap to automatically drain the separator of water.

Air Separators

Diameter of air line in in.	Approximate shipping weight in lb.	Price f. o. b. factory
1	40	$ 20
2	120	30
3	270	55
4	570	70
5	820	105
6	1320	135
7	1790	170
8	2300	225

Reheaters. When air is to be transmitted for appreciable distances, particularly out of doors, the losses in transmission are largely overcome and certain operating features gained by the use of a reheater. Air after being compressed enters the pipe line at a temperature greatly in excess of the surrounding atmosphere. By radiation this temperature is greatly reduced with a corresponding reduction in volume and, therefore, capacity for work. A reheater placed as closely as possible to the working machine will raise the temperature of the air to about 250 degrees F., increasing its volume approximately 30% with proportional gains in capacity for doing work. The reheater will also eliminate the freezing of the moisture in the exhaust ports and clogging of the tool. The reheater closely resembles a stove, the air being heated by the combustion of coal or coke in the inner shell, and the heat thus generated transmitted to the air which is around this shell.

Air Reheaters

Capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
200	400	$ 90
300	900	140
400	1500	190
500	2400	240
600	3400	290

FIG. 11. AIR REHEATER

The following data give the result of a test made in the shops of the Hansell Elcock Co., Chicago, in driving 1,608 ¾-in. rivets. Half of these rivets were driven using an ordinary air line, and half were driven using heated air from a Sterling Heater.

A plain toggle portable yoke riveter was used. The compressor cylinder was 10 ins. in diameter and 9½ ins. stroke.

An Excelsior Airometer was put in the line, at which point line

pressures and line temperatures were read. Twenty feet of 1-in. rubber hose was used between the airometer and the Sterling heater. On the discharge side of the heater a gage and thermometer were inserted for reading the temperature and pressure of the heated air. Between the heater and the riveter 27½ ft. of 1-in. insulated flexible hose was used. The following shows the results:

	Without heater	With heater
Number of rivets	804	804
Average temperature of line air	57.5°	60.0°
Average pressure, lb.	85	85
Total cu. ft. air used	14,874	8,513
Average temperature of heated air	...	396°
Cu. ft. of air used per rivet	18.5	10.58

This difference in air used per rivet equals 7.92 cu. ft. or an increase in volume of 74.7%. This increase equals an actual saving in air used of 42.7%.

Fig. 12. Horizontal Air Receiver

Assuming 1,500 rivets per day, the actual air saving equals 11,880 cu. ft. At 8 cts. per 1,000 cu. ft. this saving equals 95 cts., the cost of operating the heater equals 1 gal. oil at 10 cts. plus 8 cts. for ignition current equals 18 cts., total, a net saving of 77 cts. per day. This saving six days per week would pay for the heater in one year and leave a profit of $156.00.

The cubic feet of air given were actual airometer readings. On account of the intermittent service the heated air temperatures are not quite high enough. The actual temperature of the air supplied to the riveter was about 15% in excess of the heated air temperatures shown in the table.

Air Receivers (Fig. 12) are plain steel shells, which cool and reduce the velocity of air before it passes into the main, causing deposition of moisture where it can be drained off; they equalize the flow of air, eliminate pulsating effect of the piston strokes, thus minimizing friction losses, and serve in some degree as reservoirs of power. For best results the receiver must be close to the compressor. Secondary receivers at the other end of the air main, and near the operating machines, are often advantageous.

Air Receivers

Horizontal and vertical type

Compressor capacity for which best adapted cu. ft. per min.	Contents of receiver in cu. ft.	Weight of receiver in lb.	Price f. o. b. factory
100– 250	30	700– 825	$ 76
150– 325	43	1000–1050	98
200– 450	57	1200–1300	116
300– 650	77	1550–1600	140
500– 900	96	1750–1300	165
800–1500	150	2400–2900	220
1200–2000	192	3200–3400	260
2000–3500	280	3900–5200	340
3500–4000	380	6300	420

Proportioning Air Receivers. To determine what sized air receiver is best for the capacity of the air compressor it is proposed to install:

1st. Determine the maximum capacity of the compressor per min. in free air. (Piston displacement per min. will do.)

2nd. Calculate what volume this air will occupy at the working pressure, and this will be the required volume of the receiver.

This is a very easy calculation to make as the following will illustrate.

Suppose the maximum piston displacement of compressor per min. = 65 cu. ft.

Working pressure = 80 lb. (gage). To determine the volume of 65 cu. ft. of free air when compressed to 80 pounds pressure, the following formula may be used

$$V_2 = \frac{14.7\ V_1}{P_2 + 14.7}$$

in which V_1 = maximum piston displacement in cu. ft. per min = 65.

P_2 = Working pressure (gage) = 80 lb.

V_2 = Volume of the air at the higher pressure.

Substituting in this formula we have:

$$V_2 = \frac{14.7 \times 65}{80 + 14.7}$$

$=$ 10 cu. ft. which would be the volume of a receiver 18 in. in dia. and 6 ft. long.

The above formula determines approximately the minimum sized receiver necessary, but in making a selection a larger one is preferable. There is no drawback in having the receiver too large; a receiver is seldom too large, in fact most troubles are caused by the receiver being too small to overcome fluctuation in pressure and by not allowing the air to remain stationary long enough to cool and to deposit part of its moisture.

Cooling Devices increase compressor efficiency by reducing the temperature of the air while being compressed. This also decreases danger of explosion and provides drier air after compression.

Effect of Initial Air Temperature on Efficiency and Capacity of Air Compressors

Initial Temperature deg. F.	Initial Temperature abs. deg.	Relative capacity and efficiency
—20	441	1.18
—10	451	1.155
0	461	1.13
10	471	1.104
20	481	1.083
30	491	1.061
32	493	1.058
40	501	1.040
50	511	1.020
60	521	1.000
70	531	0.980
80	541	0.961
90	551	0.944
100	561	0.928
110	571	0.912
120	581	0.896
130	591	0.880
140	601	0.866
150	611	0.852
160	621	0.838

Air Aftercoolers

Horizontal and vertical type

Cooling surface in sq. ft.	Approximate shipping weight in lb.	Price f. o. b. factory
150	2900	$ 760
200	3500	900
300	4700	1180
500	6900	1600
750	9000	2100
1000	11000	2500
1500	13500	3300
2000	18500	4000

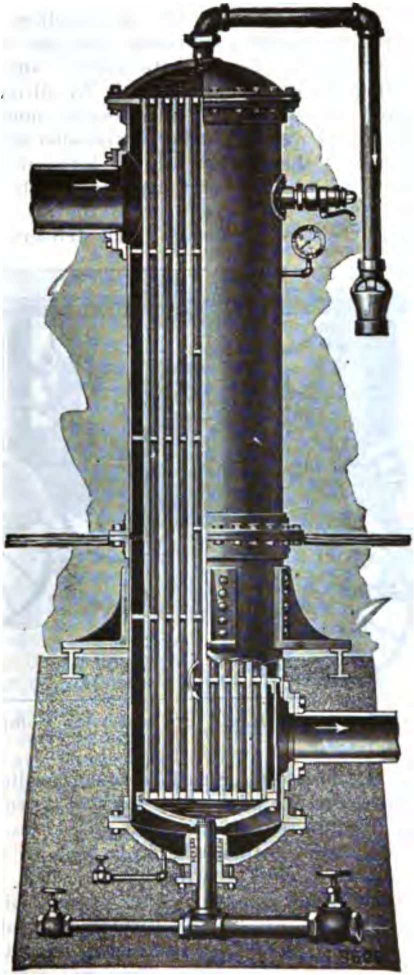


Fig. 13. Air Aftercooler

Methods of Cooling: (a) Ante-cooling; (b) cooling during compression; (c) intercooling; (d) aftercooling. Ante-cooling is by leading the air to the compressor from the coolest side of the building; or by the use of ante-coolers (similar to after-coolers). Cooling during compression is by direct contact between water and air (as in wet compressors, now nearly obsolete) or by the use of water jackets. Intercooler is used in stage compressors, to cool the compressed air between the cylinders. Upon proper cooling at this point depends largely the efficiency of stage compression. After-coolers cool the air, and therefore deposit moisture, between compressor and delivery pipe.

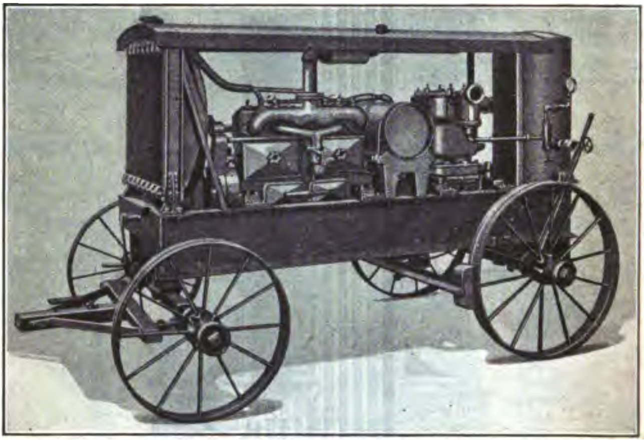


Fig. 14. Gasoline Driven Portable Air Compressor

Portable Air Compressors. Small portable gasoline and power driven air compressors are adapted to work of a temporary character requiring compressed air in small quantities, such as the laying of gas and water mains, where air tools of various types are used for cutting asphalt, tearing up roadways, rock cutting, calking lead joints, drilling and riveting of steel pipes, tamping dirt, etc. The machines are usually furnished complete with the engine and its fittings, compressor, air receiver and fittings such as valves, gages, outlets, piping, etc. They are rigged for hand transportation and may also be had fitted with tongue and single tree or bar for trailing behind a motor truck.

Where compressors of over 200 cu. ft. are required for tem-

porary work it is considered better practice to have the outfit mounted on skids rather than on a truck.

PORTABLE AIR COMPRESSORS

90–100 lb. pressure

(Gasoline driven)

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
25	1200	$ 400
50	1700	850
100	3250	1600
125	4000	1950
200	6000	2900
225	6800	3200
(Electric motor driven)		
50	1530	765
100	2950	1440
125	3600	1755
200	5400	2610
225	6120	2880

The following table gives the cost of small portable air compressors f. o. b. Michigan.

Rated capacity in cu. ft. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
5	900	$ 400
10	1400	600
21	1800	875
42	3400	1,350
40	4300	1,450

In the above table the last two compressors are of the 6 by 6 size, the 42 cu. ft. machine being driven by an 8 hp. engine and having a pressure of 75 lb. per sq. in., and the 40 being driven by a 10 hp. engine and having a pressure of 100 lb. per sq. in.

Efficiency of Compressors at Various Elevations. As it is a very common practice to use air in drills and light machines at full stroke, a table of the efficiency of compressors when the air is so used at various heights above sea level follows:

Height in ft. above sea level	Barometer inches	Efficiency of compressor, %
0	30.00	100
1000	28.88	97
2000	27.80	93
3000	26.76	90
4000	25.76	87
5000	24.79	84
6000	23.86	81
7000	22.97	78
8000	22.11	76
9000	21.29	73
10000	20.49	70
11000	19.72	68
12000	18.98	65
13000	18.27	63
14000	17.59	60
15000	16.93	58

Care of Compressors. From "Mining Engineers' Handbook," Peele.

General. So locate the compressor that parts are readily accessible. Foundations must be level in both directions and, in power driven machines, the motor and compressor must be accurately aligned.

Air Valves. Examine at least once a month, to see that there is no cutting, and that the springs, if any, are in good order.

Cutting is caused by ineffective lubrication or grit entering inlet. If the latter, remove the cause of dust, or change position of intake. Keep spare valves on hand for prompt renewal, before wear or defect becomes serious. Leaky discharge valves greatly reduce volumetric efficiency.

Air Lines. Watch closely for leaks, which are costly. A 0.25-in. hole may waste enough air to run a 2.25-in. drill.

Lubrication must be sufficient, but not excessive.

An air cylinder requires less oil than steam cylinder of same size. Use best air-cylinder oil for cylinder and valves, having a flash point not lower than 500° F. Never use kerosene to cut carbon deposits in the exhaust valves and ports, as it has a low flash point and may ignite and cause explosion.

Explosions in Compressors and Receivers

Causes: excessively high internal pressure, due less to the air pressure carried than to that produced by ignition, in compressor, piping, or receiver of an explosive mixture of air and gas from lubricant.

Lubricants in general use are: commercial cylinder oil, and a mixture of soap and water, each having its proper function. Soap and water has inferior lubricating qualities; if used alone a much greater quantity is necessary than with a proper oil.

In a compressor lubricated almost exclusively by soap and water, a deposit 2 in. thick was found, which readily ignited at 400° F. A very small quantity of oil with a flash point of 400° F. had also been used, which indicates that the use of soap is not a sure preventive of explosions. Nevertheless, it will clean the cylinder and valves without shutting down, and its use is recommended. All oils give off combustible gases when heated. The lowest temperature at which this begins is the flash point, the ignition temperature being the burning point. As ordinary lubricating oils flash at about 250° F. (a temperature below the usual working temperature of compressors), special high-flash cylinder oils should be used.

Temperature Due to Compression depends upon initial temperature, the working pressure, and the efficiency of the cooling devices.

Temperature of discharged air of a single-stage compressor is found by $T' = T\left(\frac{P'}{P}\right)^{\frac{n-1}{n}}$ where T and T' = absolute initial and final temperature, P and P' = absolute initial and final pressure, n = constant = 1.41 and $\frac{n-1}{n} = 0.29$. This formula, for adiabatic compression, is not absolutely correct, because water jackets permit very little loss of heat by radiation. Near sea level at atmospheric temperature of 70° F., P = 14, and at 80 lb. gage pressure the final temperature is

$T' = 70 + 459° \left(\frac{80 + 14}{14}\right)^{0.29} = 917°$ F., absolute, or 458° F. thermometric.

With leaky exhaust valves this temperature may be materially higher.

If no explosion occurs, CO, from imperfect combustion of the oil, and carried with the compressed air underground, may cause danger to the miners.

Precautions for avoiding high temperature:

(a) The compressor should be adapted to the conditions: Cylinder proportions for sea level are not suitable for high altitudes; (b) Intake pipe should be of wood or other insulating material, and air should be taken from as cool a place as possible outside of the engine room. A lowering of 5° F. may increase efficiency by 1%; (c) Unloader should be designed not to cause excessive heating when in operation; (d) Largest possible area of cylinder surface should be jacketed, and plenty of the coldest water obtainable used; (e) For a stage compressor use efficient inter-coolers; (f) After-coolers increase efficiency and should be used; (g) If circulating water be reused, provide ample water-coolers; (h) Place receiver inlets near the top and outlets about one ft. above the bottom, to insure cleanliness in the air; (i) Receiver should have blow-off cocks at the bottom, and man-hole for inspecting the interior; (j) Place a recording thermometer between high-pressure cylinder and receiver; (k) An automatic blowout valve, to act if temperature rises above a safe point, is advisable; (l) Inlet air should be free from dust; —washed if necessary; (m) While running, never inject kerosene into the compressor to cut carbon deposit.

Data to Be Given When Inquiring About Air Compressors. When writing for prices or other information, give as complete

data as possible regarding service to be performed and local conditions. Following points should be covered:

(a) Purpose for which the air is to be used; (b) volume of free air required, cubic ft. per minute; (c) working air pressure; (d) altitude, if over 1,000 ft. above sea level; (e) number, size, and kinds of machines to be operated by compressed air; (f) if air is to be used for pumps, give make, size, speed and head; (g) if for raising water by the air lift, state flow per min. in gal., dia. and depth of well, and height of delivery above average height of water in the well; (h) whether the demand for air will be constant or intermittent; (i) whether the compressor will be operated by steam or power; (j) if steam-driven, state steam pressure, kind and cost of fuel, type of engine preferred, and whether condensing or non-condensing; (k) if power driven, state motive power, and whether direct connection, belt, or gearing is preferred; (l) if belt-driven, give hp. at belt, and if space is limited, state maximum distance allowable between driving centers; (m) if electric-driven give particulars as to current and motor; (n) if water power is to be used, give hp. available, or head or fall of water in feet: also cu. ft. of water per min.; (o) state transport facilities. If machine must be sectionalized, state heaviest wt. allowable for a single package; (p) state style of compressor preferred. If portable, state whether for surface or underground service, and kind and source of power.

Transmission of Compressed Air in Pipes

Pipe Lines. Wrought iron and steel pipe is lap or butt-welded. As lap-weld is the stronger, it is used for the larger sizes.

Pipe up to 3 in. are usually butt-weld, though lap-weld pipe as small as 1.25 in. is made. Pipe and fittings should be galvanized inside, as the scale from black pipe may injure machines using the air. Extra-heavy pipe for high pressure may be had. Wrought iron spiral-seam riveted pipe is useful for large sizes. Rolled sheets, with punched edges ready for riveting, are convenient for transport to remote regions.

Joints. W. I. pipe lengths are connected by sleeve couplings, or by C. I. flanges into which the pipe ends are expanded or threaded. Sleeve couplings, which are suitable for all except very large sizes, should be put on with white or red lead, especially where leaks may develop in shifting ground. Gaskets are used for flange couplings: asbestos near the receiver, brown paper elsewhere. Expansion joints are necessary on long lines, but too many should be avoided as they are likely to leak.

Cost of laying gas mains of 4, 6 and 10 in. diameter, and W. I.

sleeve-joint, 6 and 8 in. air pipe, is given in Gillette's "Cost Data," pp. 1802, 1804.

Transmission Losses in compressed air pipes. The heat of compression is quickly lost in the first few hundred ft. of air main, and cannot economically be retained by non-conducting covering. Before using air expansively, it should be reheated.

Transmission Line Hints. Losses from leaky joints or unsound pipe often exceed all other transmission losses. Pipes should be inspected regularly to eliminate waste of power. Pipe of too small diameter reduces effective pressure by causing high velocity and undue friction. Velocity in mains should not exceed 20 to 25 ft. per second; in short branch pipes it may be 40 or 50 ft. Pipe with rough interior causes excessive friction loss. Each length should be cleaned of foreign substances before coupling. Lead forced into the pipe at couplings makes obstructive ridges. Surface mains should be protected, to avoid freezing of the moisture and consequent obstruction. Tees, elbows, and other fittings cause friction and should be avoided wherever possible.

Friction of Globe Valves, Tees, and Elbows

Reduction of Pressure by globe valves is the same as that caused by an added length of straight pipe, as follows:

$$\text{Added length} = (114 \times \text{dia. of pipe}) \div [1 + (3.6 \div \text{dia.})]$$

Dia. of pipe, in.	1	1.5	2	2.5	3	3.5	4	5	6
Added length, ft.	2	4	7	10	13	16	20	28	36
Dia. of pipe, in.	7	8	10	12	15	18	20	33	24
Added length, ft.	44	53	70	88	115	143	162	181	200

Reduction of Pressure by elbows and tees is equal to two-thirds of that caused by globe valves. Following are the added lengths of straight pipe equivalent to elbows and tees:

Dia. of pipe, in.	1	1.5	2	2.5	3	3.5	4	5	6
Added length, ft.	2	3	5	7	9	11	13	19	24
Dia. of pipe, in.	7	8	10	12	15	18	20	22	24
Added length, ft.	30	35	47	59	77	96	108	120	134

These additional lengths of pipe for globe valves, elbows and tees must be added in each case to length of straight pipe. Thus a 6-in. pipe 500 ft. long, with 1 globe valve, 2 elbows and 3 tees would be equivalent to a straight pipe $500 + 36 + (2 \times 24) + (3 \times 24) = 656$ ft. long.

ASBESTOS

Asbestos Building Felt and Sheathing in less than ton lots costs 14 cents per lb. and may be had in thicknesses weighing from 6 to 56 lb. per 100 sq. ft.

Asbestos Mill Board is made in standard sheets, 40 by 40 in. and 42 by 48 in. It varies in thickness from 1/16 to 1/2 in., and in weight from 4 to 27 lb. per sheet. The price in ton lots per lb. is $0.085; in less than ton lots, in crates of approximately 400 lb., $0.09 per lb.; and in quantities of less than 400 lb., its price per lb. is $0.125.

Transite, Asbestos Wood used for fireproofing work, ventilators and smoke jackets, comes in standard sheets 36 by 48 in., 42 by 48 in., and 42 by 96 in. It may be had in all thicknesses from 1/8 in. to 2 in., and weighs from about 1.4 to 20 lb. per sq. ft. It costs in less than ton lots $0 11 per lb.

Asbestos cements are used for covering boilers, domes, fittings, etc., and all irregular surfaces, and may be used over asbestos air cell boiler blocks, when it makes an excellent covering. When mixed with water to a consistency of mortar and applied with a trowel, it forms a light porous coating which is the most efficient non-conductor. The cost of this cement is $4.50 per bag of 100 lb.

SECTION 2

ASPHALT PLANTS

Portable Asphalt Mixing Plant. A plant of the two unit type having a capacity of 800 sq. yd. consists of the following:

1st Unit: Boiler, engine, cold material elevator, screen, sand and stone storage bin, measuring box, weighing bucket, mixer, complete all mounted on steel frame and wheels, weighs 44,200 lb. and costs $11,500.

2nd Unit: Portable steam melting kettle, 3,000 gal. capacity, mounted on wheels, weighs 11,300 lb., and costs $2,300.

Fig. 15. Two Unit Portable Asphalt Plant.

A three unit plant similar to the above in capacity is as follows:

1st Unit: Mixer, drier, etc., weight 34,200 lb., price $9,000.

2nd Unit: 40 hp. portable boiler and 25 hp. steam engine, weight 12,600 lb., price $3,200.

3rd Unit: Same as second unit in above outfit.

A three unit plant similar to the above rated at 1,250 sq. yd. capacity is as follows:

1st Unit: Mixer, drier, etc., weight 38,000 lb., price $12,500.
2nd Unit: 50 hp. portable boiler, 25 hp. engine, weight 13,100 lb., price $3,700.
3rd Unit: Two 2,400 gal. portable steam melting kettles, weight 19,600 lb., price $3,700.

Fig. 16. Portable Asphalt Plant.

Portable Road Asphalt Plant. The following is a description of a plant made in three sizes. These plants consist of three units. For the plant having a rated capacity of 75 yards, or the equivalent Topeka Mixture Asphaltic Concrete-Asphalt Macadam, or any of the patented hot mixture asphalt pavements per hour, the first unit consists of a sand drum, capacity 8 tons per hour; mixer, capacity 5 cu. ft.; sand bin with rotary screen divided into two compartments so that Sheet Asphalt Topping, Topeka Mix or Asphalt Concrete can be laid without change, capacity 5 tons; measuring box arranged so that hot sand and stone for each batch is weighed quickly and accurately; asphalt bucket arranged so that the asphalt for each batch is accurately weighed; mounted on all-steel trucks. The approximate shipping weight of this outfit is 35,000 lb. and it costs $10,000.

The second unit consists of a 30 hp. locomotive type portable boiler and a 25 hp engine, mounted together on an all-steel truck. It weighs 10,800 lb for shipment and costs $2,500.

The third unit consists of a portable melting kettle having a capacity of 12 tons, mounted on steel trucks and furnished with

two platforms. The shipping weight is approximately 12,000 lb., and the price is $1,750.

The plant having a capacity of 125 sq. yd. has a sand drum with a capacity of 12 tons per hour; a 7 cu. ft. batch mixer; a 7 ton sand bin; measuring box, asphalt bucket and is mounted on trucks. It weighs approximately 42,000 lb. for shipment and costs $12,500.

The second unit is the same as in the 75 yd. size. The third unit is also the same as in the 75 yd. size.

The plant having a capacity of 180 sq. yd. has in the first unit a sand drum, capacity of 18 tons per hour; a 9 cu. ft. steam jacketed mixer, a 10 ton sand bin, measuring box, bucket and is mounted on steel trucks. It weighs approximately 46,000 lb. for shipment and costs $15,000.

The second unit consists of a 50 hp. boiler with a 40 hp. engine mounted on it with belt and weighs 16,000 lb. for shipment and costs $3,000.

The third unit consists of two of the same kettles as used in the other outfits.

The following men are required to run any of the three sizes; one additional man for the 180 yard size:

1 Drum fireman.
3 Men on the mixer platform for sheet asphalt and other mixtures requiring the addition of dust.
2 Men on the mixer platform for Topeka mix or other pavement not requiring additional dust.
1 Man to fire and attend to the temperature of the kettles.
1 General foreman.
1 Engineer if steam power be used; he can be dispensed with if electric power be used.
1 Oiler and general handy man.
Sufficient laborers to carry wet sand and stone to the cold material elevator.

For municipalities, these portable plants may be used as stationary plants by removing the axles and wheels, setting up the plant on a permanent concrete foundation and surrounding the plant with a suitable building of light construction.

This plant is illustrated by Fig. 17.

A portable asphalt mixing plant has the following dimensions: length over all 35 ft., width over frame 7 ft. 3 in., width over wheels 12 ft. 3 in., wheel base 22 ft., height over all when working 21 ft. 9 in., and height over all when the elevator is taken down for travel 12 ft. The specifications are as follows: Asphalt kettle capacity 1500 gallons or approximately 26 barrels; boiler

48 in. by 104 in., vertical, 34 hp.; engine 10 in. by 10 in., vertical, 25 hp.; boiler water tank, 300 gallons; traveling speed one mile per hour; capacity of batch ½ cu. yd. or 1,000 lb.; weight of machine, approximately 26 tons. Price f. o. b. factory $9,000.00.

An asphalt mixer was used in Lincoln Park, Chicago, during 1910 to construct an asphalt surfaced driveway. The road was

Fig. 17. Dryer and Mixer Unit.

40 ft. wide x 4,631 ft. long, and had 2 inches of asphalt on an 8 in. base of crushed stone. The total amount of asphalt was 22,318 sq. yds. The material was mixed in an asphalt mixer in the following proportions:

	Lbs.
1 part torpedo sand	168
1 part bank sand	165
3 parts ½ in. stone	504
Asphalt	81
Total 7 cu. ft. or 1 box	921

The total costs were as follows:

Labor on stone, per sq. yd.	$0.498
Labor on asphalt, per sq. yd.	.352
Stone for base, per sq. yd.	.394
Asphalt material	.394
Total per sq. yd.	$1.638

Labor cost of curb, per lin. ft.	$ 64
Material cost of curb, per lin. ft.	.21
Total cost of curb	$0.85

These costs include all repairs to the plant, but no depreciation The cost of the plant was as follows:

Link Belt Co., asphalt mixer	$ 5,590
Gasoline tractor	1,200
6-ton roller	1,800
15-ton roller	1,500
Asphalt tanks and tools	1,000
Total value of plant (1910)	$11,090

The municipal asphalt repair plant of New Orleans, La., was erected on a lot 175 ft. x 260 ft., and covers about 1,500 square feet of ground.

The cost of plant was as follows (1906 prices):

Demolition of old garbage plant buildings	$ 475.00
Asphalt plant — Warren Bros. Asphalt Paving Co.'s contract, $16,862.50; city alterations and additions, $2,736.50	19,599.00
Yard fences and gates	859.00
Switch tracks	1,189.00
Yard pavements and drains	6,721.00
Tower tank and filter	1,330.00
Water pipes and outlets	1,015.00
Waterhouse and platform	1,471.00
Asphalt shed	289 00
Blacksmith shop and equipment	222.00
Stable, rolling pen and wagon shed	5,311.00
Stone crusher and storage bin	1,966.00
Yard material bins	332.00
Office and store room building	5,509.00
Landing bins and roads	1,432.00
Lighting	352.00
General cleaning of premises	298.00
Total	$48,370.00

In addition to 134 tools of various kinds included in the contract price, the plant is furnished with the following: 1 roller-mounted platform scales; 1 4-wheel hand truck; 12 wheelbarrows, 18 shovels; 10 axes; 6 picks; 8 crowbars; 8 sledge hammers; and a number of small tools. The shed tools consist of the following: 2 tool boxes; 18 street barriers; 1 8-ton steam roller; 1 3½-ton steam roller; 1 1,000-lb. hand roller; 1 fire wagon; 1 mixing kettle; 18 asphalt irons; 66 asphalt axes; 107 picks; 18 mattocks: 142 shovels; 24 wheelbarrows; 6 axes; 200 ft. of hose: 6 sledge hammers; 8 chisels; 10 iron bars; and other small tools. The testing laboratory is equipped with cement testing apparatus, oil testers, brick testers, etc.

In addition, 17 mules, 3 horses, 8 sets harness, halters, blankets, etc., for the stable, and 10 wagons, 8 carts, 2 farm wagons, 1 float dray and 1 buggy were purchased.

This equipment cost as follows:

Live stock, harness and stable equipment	$ 6,197.00
Rolling stock and equipment	3,180.00
Plant tools	837.00
Street tools	5,492.00
Office furniture	447.00
Laboratory equipment	1,490.00
Total	$17,643.00

Additional equipment was as follows:

1 7-ton steam road roller	$1,113.00
1 steel road grading machine	150 00
1 700-gallon capacity road sprinkler	396.00
Rolling stock	1,027.00
Railroad plows with extra points	39.00
Wheel scrapers	140.00
Harness	139.00
Live stock	1,700.00
Total	$4,704.00

From September 1, 1906, to August 31, 1907, supplies cost as follows:

	Av. Unit Cost	Total
Asphalt, 465.99 tons	18.50	$8,561
Fluxing oil, 125,527 lb.	.0075	940
Naphtha, 6,753 gal.	.15	1,019
Lake shore sand, 2,580 cu. yd.	.99	2,566
River sand, 1,779 cu. yd.	1.64	2,920
Tchefuncta River sand, 250 cu. yd.	1.60	400
Mineral dust, 321 tons	5.50	1,764
River gravel, 564 cu. yd.	2 27	1,272
Cement. 1,936 bbl.	2 04	3,944
Coal, 389 tons	2.84	1,105
Clay gravel, 3,178 cu. yd.	1.50	4,786
New small granite blocks, 3,240	.07	227
Old small granite blocks, 4,600	.04	184
New building brick, 9,000	...	98
Old building brick, 8,500	...	25
Pine wood, 49¾ cords	5.68	283
Oak wood, 41½ cords	6.74	280
Lake shells, 3,618 cu. yd.	1.46	5,304
Brickbats, 696 cu. yd.	1.48	1,032
Cast iron, 32,924 lb.	...	1,289
Drain pipes and Ys, 3,026 lin. ft.	...	979
Laboratory supplies	...	24
Office supplies, stamps, etc.	...	436
Engineers' supplies	...	606
Oats, 122,172 lb.	.015	1,820
Bran, 6,600 lb.	.01	66
Hay, 39¾ tons	24.72	983
Stable supplies	...	309
Blacksmith supplies	...	87
		$43,309

During the same period of time the plant turned out 88,947 cubic feet of wear surface which equals 49,415 square yards of 2 inch pavement.

The largest day's run was 205 boxes of wearing surface mixture. One box, or 9 cubic feet, will lay 5 square yards of 2-inch pavement.

Operation Cost, Municipal Asphalt Plant of the District of Columbia. Itemized costs for the operation of the District of Columbia municipal asphalt plant are contained in a report by the engineer department for the year which ended June 30, 1918. The plant output for the year was 185,952 cu. ft. of material, consisting of 151,152 cu. ft. of old-material mixture 22,056 cu. ft. of asphaltic concrete mixture, and 12,744 cu. ft. of topping mixture. The plant was operated for 214 days with an average daily output of 869 cubic feet.

Hauling by motor truck was introduced during the year for hauling the hot mixture, and was found to be both economical and advantageous. About 90% of the hot haul was done by trucks.

Municipal Asphalt Plant Costs at Washington, D. C.

Based on 1 cu. ft. of Mixture

Old-Material Mixture

Material cost:		
Oid material, 0.6 cu. ft., at $1.05 per cu. yd.		$0.0233
Sand, 0.34 cu. ft., at $1.43 per cu. yd.		.0180
Limestone dust, 2.1 lb., at $3.63 per ton		.0038
Asphaltic cement, 4.12 lb., at $19.10 per ton		.0393
Total cost of material per cubic foot		$0.0844
Manufacturing and placing cost:		
Plant labor	$0.0593	
Hot haul	.0498	
Street laying	.1974	
Maintenance of plant and tools	.0188	
Supervision	.0432	
Total		$0.3685
Total cost per cubic foot		.4529

Asphaltic Concrete Mixture

Material cost:	
Screenings, 0.5 cu. ft., at $1.30 per ton	.0331
Sand, 0.5 cu. ft., at $1.43 per cu. yd.	.0265
Limestone dust, 4.2 lb., at $3.63 per ton	.0076
Asphaltic cement, 9.16 lb., at $19.10 per ton	.0875
Total cost of material	$0.1547
Manufacturing and placing cost	.3685
Total cost per cubic foot	$0.5232

Topping Mixture

Material cost:	
Sand, 1.0 cu. ft., at $1.43 per cu. yd.	$0.0530
Limestone dust, 4.2 lb., at $3.63 per ton	.0076
Asphaltic cement, 9.16 lb., at $19.10 per ton	.0875
Total cost of material	$0.1481
Manufacturing and placing cost	.3685
Total cost per cubic foot	$0.5166

A summary of the costs of material, operation, hauling, laying, maintenance and supervision is given in the table. The cost of minor repairs to sheet-asphalt pavements during the year averaged 1.7c. per square yard on a yardage of 3,064,706. The average costs for the past 10 years have been as follows: 1908, 3.8c.; 1909, 2.3c.; 1910, 2.6c.; 1911, 2.2c.; 1912, 2.4c.; 1913, 2c.; 1914, 1.9c.; 1915, 1.9c.; 1916, 1.8c.; 1917, 1.5c. The plant began operations in 1912.

ASPHALT PAVING AND REPAIRING EQUIPMENT

Surface Heaters. A heater primarily designed for heating old asphalt pavements in repairing, but which may also be used for general heating and drying purposes, burns either gasoline or kerosene. The heater weighs approximately 615 lb. for shipment and costs $190. It is made in the following sizes:

Hood size	Burners
4 by 5 ft.	5
3 by 4 ft.	4
2 by 4 ft.	3
1 by 4 ft.	2

Another make of surface heater has the following specifications:

Fire Pan — 6 ft. by 6 ft. by 6 in., flat top. Can be raised and lowered by one man.
Tanks — main tank, 35 gal., auxiliary tank, 18 gal., total 53 gal.
Consumption — 6 gal. per hr., kerosene.
Wheels — 36-in. staggered spokes, steel.
Fittings — air and oil gauges, valves, etc.
Shipping weight — 1,300 lb.
Price — $525, f. o. b. Detroit, Mich.

The manufacturers claim that this heater will remove 500 sq. yd. to a depth of one inch in eight hours.

Kerosene Tool Furnace. This furnace is designed to replace the old style fire wagon to get away from the smoke and dirt and time lost in heating the tools. With the kerosene furnace it takes about 15 minutes to heat up the tools ready for use.

This furnace has the following specifications: Capacity — ap-

proximately 15 assorted tools, rakes, shovels, tampers, etc.; three burners, flame plays directly on the tools; two 18-gal. tanks, 30-in. steel wheels, fittings, gauges, etc., complete. Shipping weight 1,050 lb., price $320, f. o. b. Detroit, Mich.

Fire wagon for heating asphalt tools made of heavy steel channel sections and equipped with uprights, cross bar and hooks, mounted on metal wheels, has a shipping weight of 1,360 lb., and costs $155.

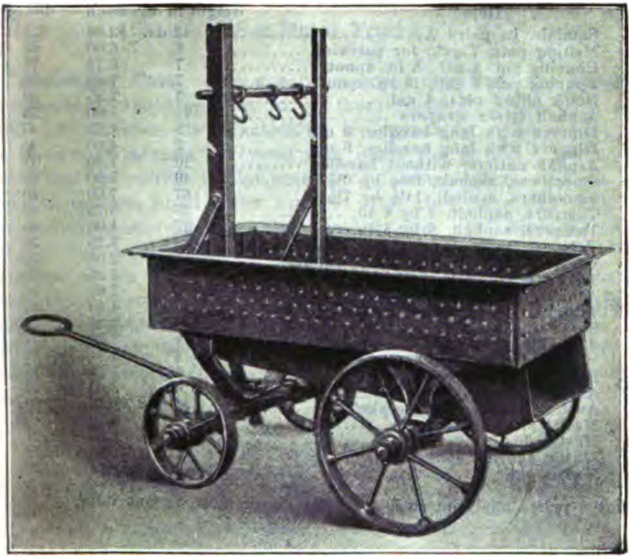


Fig. 18. Fire Wagon.

Hand roller for patching weighs approximately 1,150 lb. for shipment and costs $135.

Old material pan for re-heating old asphalt is about 10 ft. long, 4 ft. wide and 14 in. deep. It has a shipping weight of 725 lb. and costs $125.

KETTLES

Capacity in gal.	Kind	Approximate weight in lb.	Price
10	Portable patrol kettle	135	$ 40
50	Stationary rectangular kettle	280	96
100	Stationary rectangular kettle	405	146
150	Stationary rectangular kettle	585	162

50	Portable rectangular kettle	700	180
100	Portable rectangular kettle	1145	241
150	Portable rectangular kettle	1305	270
100	Stationary round mastic kettle	650	142
150	Stationary rectangular mastic kettle	670	115
400	Portable continuous kettle with hood	4800	746
600	Portable continuous kettle with hood	....	910

Asphalt Tools

Item	Approximate weight in lb.	Price each	Price doz.
Sandals, in pairs	42 dz.	$2.00	$20
Melting pots, 7 gal., for patching	8	6.00	68
Pouring pot, 4 gal., 8 in. spout	7	6.75	75
Pouring pot, 4 gal., 10 in. spout	7	7.25	80
Brick filling pots, 4 gal.	7	7.25	80
Asphalt street scrapers	10	5.00	54
Dippers with long handles, 9 qt.	9	4.25	47
Dippers with long handles, 6 qt.	7	4.00	45
Asphalt cutters, without handles	10	1.60	18
Smoothers, asphalt, 10½ by 6½ in.	46	5.00	55
Smoothers, asphalt, 14½ by 7½ in.	67	7.00	80
Tampers, asphalt, 8 by 6 in.	35	3.75	42
Tampers, asphalt, 8 by 8 in.	37	4.00	45
Tampers, asphalt, 6 by 6 in.	29	3.25	36
Tampers, asphalt, 5½ by 2½ in.	16	2.00	22
Tampers, concrete, 8 by 8 in., handles	10	3.25	35
Asphalt rakes	5	2.60	28
Two-man stone rake	10	4.00	45
Stone and binder fork	8	3.25	35
Asphalt patching hoes	11	3.30	37
Wire push brooms, handles	4	1.50	15
Rattan push brooms, handles	2½	1.50	15
Asphalt shovels, solid socket	6	2.00	22
Asphalt shovels, open socket	4½	1.75	20
Mastic stirring rods	10	3.50	40
Mastic floats	4½	1.95	21
Mastic shovels, long handles	4¼	1.85	20
Mastic pails	9	1.80	20

Dozen prices apply on each order for six or more on one item.

SECTION 3

AUTOMOBILES

(See Motor Trucks.)

Passenger Cars. For use of a superintendent, the passenger automobile, enabling him to go from place to place with speed and convenience, is practically indispensable. Their first cost is known to almost everyone who reads the papers, but the cost of operation, which is the important feature, seems to be a mystery to owners until a few months after they have had their cars in commission. The medium priced car, say from $1,200 to $1,800 for a five-passenger touring car equipped, is worth at the end of its first year a little less than two-thirds of its first cost if in proper repair, newly painted and usually with two new tires. After the first year the rate of depreciation is a little less, say, 25% of the original cost when new. It is reasonably safe to figure about as follows for a standard American car:

Depreciation per year	25%–40%
Interest	6%
Repairs and painting	20%–40%
Storage (garage) (if in cities) (Less in country)	15%–30%
Gasoline and oil, 10,000 miles	12%–36%

These figures are intended to represent average conditions, and may easily be exceeded by careless handling or rough usage, and, on the other hand, may be too high for certain conditions. The very high priced cars will not depreciate as fast as 25%, while the very low ones may depreciate faster than 40%. If given less than average use the repair bill will be low, and the gasoline and oil costs will be reduced in proportion. If not used at all, but stored at a minimum rate of 5%, the above costs will foot up to 36% of the cost of the car new, while with very moderate usage 50% would seem none too high. The proper unit for gasoline cost is that of the car mile, but here it has been assumed to be on the basis of gasoline at 35 cents per gallon and twelve car miles per gallon of gasoline. I have

allowed ¼ cent per mile for oil, making 3.5 cents per mile in all, or $350 for 10,000 miles, which would be 23% of the first cost of a $1,500 car. The other figures are properly in terms of percentage of first cost per year, and the fuel costs have been assumed as above to get them into the same units for comparison. The last item is relatively unimportant, and becomes insignificant if the car is not much used.

If the average $1,500 car is used 200 days in the year, averaging fifty miles per day, its daily cost on the above basis will be $9.00, which, allowing for chauffeur and overhead expenses, checks with the ordinary rental charges. The price of gasoline is not likely to be lowered, but is gradually advancing, and repair and storage rates tend to increase with the lapse of time. Consequently, the total percentage for annual maintenance cost, in terms of the selling price, is likely to grow from year to year the country over, the selling prices tending to steadily decline until they reach a standard cost of production plus standard overhead charges and reasonable profits.

Many figures of "sworn statements" as to repair costs have been published in the interests of the manufacturers of cars. These may be useful as advertising matter, but they are hardly a safe guide when financing a purchase.

SECTION 4

BACKFILLING MACHINES

In trenching work where machines are used for excavation, the cost of backfilling (by hand) is frequently higher than that of excavation, and there is opportunity for considerable saving in this item by the use of machines instead of hand labor.

The Dragline Backfilling Machine. The wheel type without traction is made in the smaller sizes. It is designed to be drawn

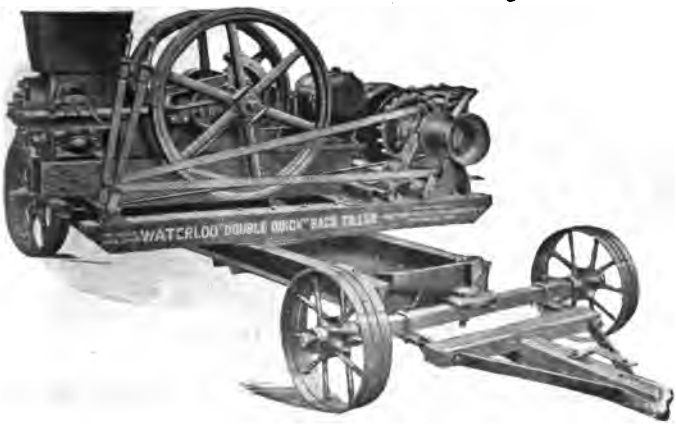


Fig. 19. Gasoline Backfiller.

by a horse or trailed behind a motor truck to the job. It is moved along with the work on the job by its own power, by the use of the winch head and an anchored line. This type of machine equipped with a pulling drum having a capacity of 175 ft. of ½-in. cable and a maximum capacity of a 1,700-lb. load at a single line speed of 85 ft. per min. weighs approximately 4,000 lb. Price f. o. b. factory, $700.00.

The following table gives the size, weight and price of the wheel type with traction.

Gasoline Driven Backfilling Machines

Wheel type, with traction

Horse power	Approximate shipping weight in lb.	Price f. o. b. factory
5	2800	$ 820
6	3400	890
7	4000	950
8	4600	1000
9	5200	1050

Fig. 20. Backfiller with Traction.

The following table gives the size, weight and price of the caterpillar traction type.

Gasoline Driven Backfilling Machines

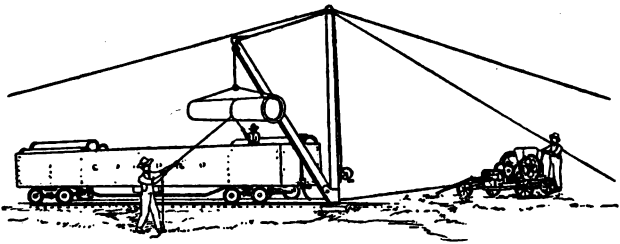
Caterpillar traction type

Horse power	Approximate shipping weight in lb.	Price f. o. b. factory
10	9400	$2350
12	10500	2500
15	11700	2750

Backfilling machines equipped with a winch head may be used for various purposes besides backfilling, such as raising telegraph poles by a gin-pole, pulling cable through conduit, pulling crib-

bing, lowering pipe into a trench or unloading it from cars (see Figs. 21 and 22), and many others where temporary power is required.

Backfilling Wagons. The following notes are from the *Excavating Engineer*: By mounting a triangular 3 yd. box on an ordinary wagon body, a Chicago contractor was able to avoid piling dirt on streets and rehandling in a sewer job. The top of the box is 10 ft. above ground and the floor forms a chute starting at the top on the outside and extending at a 45-



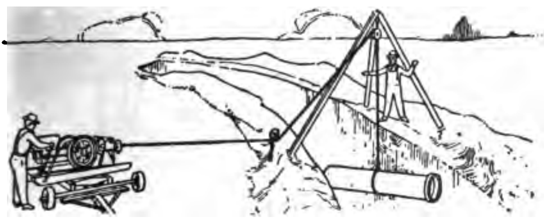


Fig. 21. Unloading Pipe from Car.
Fig. 22. Lowering Pipe into Trench.

deg. angle past the side of the wagon for a distance of about 3 ft. This overhang is sufficient to permit discharging the material into the trench and still keep the wheels of the wagon from crumbling the edge of the trench. The discharge gate consists of a door, hinged at the top, controlled by a lever beside the driver's seat. See Fig. 23.

Backfilling with a Road Roller. The following notes are taken from *Engineering News*, May 13, 1915:

For rapid, cheap and effective backfilling of trenches the Los Angeles City Water Department has utilized its steam road roller, rigged up to what the force calls a "pusher," the contrivance being capable of doing three times the amount of work

that can be accomplished by an average scraper gang, at one-half the expense. The device is shown in the illustration. It consists of a piece of Oregon pine, 2 x 12-in. by 3 ft. long, shod with iron, well braced and bolted to a 6 x 6 Oregon pine beam, 16 ft. long, attached after the manner of a wagon tongue to the front of a 7-ton 10-hp. Kelly-Springfield road roller. The beam is supported by tackle from a mast of 4 x 4 Oregon pine fastened on a hinge to the frame of the roller and held in place by wire guys.

This machine was used on backfilling 5 miles of ditch excavated for a 40-in. riveted steel main, the trench being 5 ft. deep and 5½ ft. wide. The spoil bank, which was of reasonable dry earth, had

Fig. 23. Piling Dirt on Streets and Rehandling Avoided by Use of These Wagons.

a base of approximately 12 ft. and a height of about 6 ft. After the men became accustomed to the use of the equipment, with every forward trip of the roller a cubic yard of fill went into the trench. Not only was the machine satisfactory from the volume of earth moved, but it was found that the roller could back up to a freeway, go forward again and have its load in the ditch in the time that a two-horse fresno was getting into position for its load.

The machine on this ditch in an 8-hr. day did an average of 450 lin. ft. of backfill, the expense being one man to guide the "pusher" or plowshare at $2.50; a second man to raise and lower the tongue by means of the tackle at $2.50; a steam engineer for the roller at $3.50; and 800 lb. of coal at $13.50 per ton —

a total of $13.90. (This rate would be considerably lowered in a locality where cheap coal is to be had.) On the same work before the contrivance was put in service two two-horse scrapers and drivers at $3.50 each and one man as helper at $2.50 did 150 lin. ft.

In working out the final form it was found that the length of tongue should be nearly as long as the base of the spoil bank to be moved; also that the device must be very strongly built.

Fig. 24. Steam Roller with Pusher Attachment Backfilling a Pipe Trench.

Two conditions necessary for good work are a fairly level ground with no obstructions in the way and sufficient room in the street for the length of roller and tongue to get at the outer edge of the bank. It is quite possible to take the bank at an angle, but the best results are accomplished when the bank is hit squarely. Also, the use of the machine involves stopping of traffic in the block in which it is working.

SECTION 5

BAR CUTTERS

A cutter which is operated by a lever and takes round steel bars up to ¾-in. in size, weighing about 130 lb., costs $16.

A cutter taking flat bars up to ⅜ by 3 in., weighing 120 lb., costs $13.

The above prices do not include stands.

A machine with stand which cuts twisted squares up to 1 in., and rounds up to 1⅛ in., weighing about 315 lb. is priced at $95.

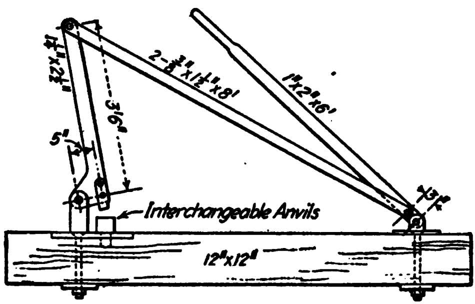


Fig. 25. Home Made Bar Cutter.

Home Made Bar Cutter. Mr. L. A. Francisco in *Engineering Record* has described a home made bar cutter as follows: To a 12 x 12-in. timber is bolted a 1-in. thick steel plate having two holes over the center-line of the timber. Through one of these passes the eyebolt which forms the hinge of the jaw. Into the other fit several different sizes of anvil-blocks, for cutting different sizes of steel bars. The movable blade of the shear was made from an old bridge eyebar fitted with a cutting edge of hardened tool steel. The leverage shown in the sketch Fig. 25 makes it possible to exert a pressure of about 70,000 lb. on this edge.

SECTION 6

BARGES AND SCOWS

Wood Barges. The following data are vouched for by Mr. C. W. Dunham (*Professional Memoirs*), and were published in *Engineering and Contracting*, July 17, 1912. They cover a very interesting and instructive record of initial cost, repairs and life of various classes of floating plant used on the Upper Mississippi Improvement during the last thirty years.

During this period of thirty years, this improvement has owned and employed 282 barges (scow), 12 barges (model), 90 quarter-boats, office-boats and store-boats, 3 steam drill-boats, 4 dipper dredges, 5 hydraulic dredges, 7 pile drivers, 23 dump boats, 3 snag-boats, 16 tow-boats of various sizes, and a very large number of small steam and gasoline launches, motor and ordinary skiffs, pontoons, and other small pieces.

It will not be practicable within reasonable limits to follow the destinies of so many pieces, and therefore certain characteristic groups of various kinds are taken, from the experience of which conclusions may be drawn. Pieces built within the last few years are not considered. I would say that none of the pieces up to 1908 had any kind of wood preserver except, occasionally, Carbolineum Avenarius laid on with a brush, but during the past three years, 80 barges, 4 dumps, 3 dredges, 33 pontoons, and 3 quarter-deck boats have been built, of which most of the lumber in the hulls has been treated with creosote by the open tank or dipping process. Sufficient time has not elapsed to show the value of this treatment.

In 1911 we treated lumber in barge construction by a pressure process.

Scow Barges. The standard barges used in this district are 100 x 20 x 4½-ft. and 110 x 24 x 5-ft. in size.

The barges used in the earliest years of this improvement for carrying rock and brush, were mostly of smaller size than those at present employed, were built of white pine, and with calking and nominal repairs, gave good service for periods ranging from eight to eleven years.

Model Barges. Early in the improvement six oak model barges,

SMALL BARGES USED EARLY IN THE IMPROVEMENT. ALL BUILT OF WHITE PINE UNTREATED

No.	Size ft.	Builder	Where built	Year	Cost	Longevity, years	Remarks
1–8	80 x 16 x 4	Wilson	Prescott	1881	$560	9	With one exception, and that due to accident, these barges gave good service for 9 years, and several were used for carrying brush a few years longer.
10–12	65 x 16 x 4	Eckhardt	Davenport	1881	720	11	Gave good service for 11 years and brush service for several more.
20–24, 36–39, 47	81 x 16 x 4	Hired labor, U. S.	Clinton and Davport	1881	...	9	Do.
25–35	66 x 16 x 4	Eckhardt	Davenport	1881	548	8–10	Do.
65–72	80 x 16 x 4	Do.	Do.	1882	685	9	Do.
76–85	80 x 16 x 4	Diamond Joe	Dubuque	1882	660	8	Do.

Group I

Built by Isherwood, Davenport, 1891; 100 by by 4 feet, White Pine. Cost $770 each.

No.	Repairs										
	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	Total
15	$48	$51	$170	$278	$58	$ 52	$21	$3	Bad	Condemned	$681
19	0	0	104	8	58	169	2	Bad	Do.	Do.	341
37	48	51	152	26	60	152	16	Do.	Do.	Do.	505
44	0	14	32	0	60	63	91	Do.	Do.	Do.	260
78	0	0	0	0	59	46	Bad	Do.	Do.	Do.	105
96	0	0	32	0	59	0	0	Do.	Do.	Do.	91
114	48	23	220	0	60	149	0	3	Do.	Do.	503
117	0	29	185	0	58	131	49	0	Do.	Do.	452

With one exception (78) the good life of this group of barges was seven years. The large repairs on four barges were due to accidents, collisions, snags, etc.

Group II

Built by Whitney, Rock Island, 1891; 100 by 20 by 4 feet, White Pine. Cost, $770 each.

No.	Repairs 1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	Total
1	$48	$51	$192	$29	$58	$167	$16	Bad	Bad	Condemned	$561
2	0	0	78	0	0	56	0	0	Do.	Do.	134
18	0	23	60	0	0	40	62	0	Do.	Do.	185
39	48	82	144	0	60	80	11	0	Do.	Do.	375
43	17	33	0	60	31	0	Bad	Bad	Do.	Do.	141
82	92	0	29	0	0	145	0	0	Do.	Do.	266
115	48	25	74	5	58	149	0	0	Do.	Do.	359
116	0	0	3	0	60	37	91	Bad	Do.	Do.	191

With one exception (43) the good life of this group was seven years.

Group III

Built by Kahlke, Rock Island, 1892; 100 by 20 by 4 feet, Douglas Fir. Cost, $806 each.

No.	Repairs to Barges 1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	Total
143	.....	$ 7	...	...	...	$ 2	$115	$ 66	$ 8	$406	...	$160	$ 32	$ 44	$93	$ 93	*	$1,026
144	.....	50	...	...	$42	34	139	215	...	170	...	99	30	74	19	144	*	1,016
145	.....	24	...	...	...	37	124	200	8	144	...	122	19	47	98	116	*	939
146	.....	100	...	...	16	155	220	115	...	300	$16	143	30	78	*	...	...	1,173
148	.....	108	...	...	8	90	160	155	...	215	...	151	90	126	*	...	...	1,103
149	.....	87	$15	...	6	82	40	64	...	276	...	8	50	**	*	...	...	628
150	.....	107	...	...	15	101	134	83	30	430	***	...	...	...	...	...	...	900
151	.....	78	28	...	20	140	137	188	...	279	41	189	174	10	*	...	...	1,284
152	.....	100	...	...	24	70	55	190	150	489	...	50	170	25	*	...	...	1,323

Longevity fifteen and sixteen years, with deck repairs and partial rebuilding. * Condemned. ** Bad. *** Wrecked.

Groups IV and V

Built by Batchelder, Stillwater, 1894; 100 by 20 by 4 feet, Douglas Fir. Cost, $800 each.

	Repairs to Barges																	
No.	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	Total
168	...	...	...	...	...	$ 38	$ 17	$ 8	$352	...	$ 52	$32	$27	$ 93	$ 45	...	$36	$700
169	...	...	...	...	$33	...	91	8	326	...	56	16	26	90	37	$12	35	730
170	...	...	...	...	27	28	...	14	85	...	387	25	26	93	205	...	**	881
171	...	...	...	...	35	23	...	18	109	...	350	23	4	70	74	*	...	706
172	...	...	...	...	...	22	17	51	385	$10	53	55	25	...	10	72	34	734
173	...	...	...	...	...	33	30	...	231	76	52	16	18	...	12	57	36	564
†174	...	...	$24	...	34	10	112	188	115	...	84	56	36	107	192	*	...	958
†176	...	...	...	$1	3	5	108	30	89	15	251	38	19	102	***	...	...	661
†177	...	...	...	...	10	110	204	...	75	...	422	14	21	*	...	...	...	856

Nos. 168, 169, 172 and 173 were partly rebuilt in 1902; 170 and 171 in 1904. All of these, except 171 and 173 are now (July, 1911) in fair condition. All of these went eight years with merely nominal repairs, such as calking. Repairs surprisingly small. * Condemned. ** Fair. *** Bad. † Built by Kahlke, Rock Island, 1894; 100 by 20 by 4 feet. Fir. Cost, $806 each. Good life; twelve years, with nominal repairs and calking.

Group VI

Built by Whitney, Rock Island, 1895; 100 by 20 by 4 feet; Fir gunwales, remainder White Pine. Cost, $790.

No.	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	Total
185	$18	...	...	$ 54	$193	$30	$ 85	$41	$50	$ 45	$ 1	*	...	...	...	$ 517
186	24	$10	...	102	17	18	73	...	...	47	63	$326	$225	$445	†$164	1,514
187	18	...	...	55	84	9	393	41	50	165	15	645	192	119	†3	1,789
188	..	14	$37	93	62	...	381	...	...	70	61	107	104	57	†56	1,042
189	..	4	91	100	125	24	309	41	50	155	35	625	161	*	...	1,720

† Fair. A good life, but repairs in later years large and perhaps unjustifiable. Three of these still in use, 1911. * Condemned.

Group VII

Built by United States, Fountain City, 1895–1896; 100 by 20 by 4½ feet; Douglas Fir. Cost, $768 each.

No.	Repairs to Barges 1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	Total
192....	...	$35	$ 41	$68	...	$15	$ 83	$174	$114	$ 55	$ 49	$395	$145	$220	$276†	$1,675
193....	...	...	272	69	...	...	169	26	100	205	50	314	68	145	259†	1,677
194....	...	...	...	69	...	...	134	48	36	357	49	442	284	105	259†	1,783
196....	...	...	...	56	...	...	233	26	242	5	49	150	59	*	...	820
197....	...	...	87	28	$27	...	207	77	170	55	85	*	...	...	...	736
198....	...	...	...	24	...	...	181	45	51	259	107	188	39	*	...	894
199....	...	...	...	66	...	...	106	46	243	128	50	*	...	...	...	639
200....	...	...	42	64	...	15	159	26	38	5	**	*	...	...	...	349
201....	...	...	...	25	24	...	56	21	169	102	49	400	216	*	...	1,062

A good life, but repairs toward the end too large. Three still in use, 1911. * Condemned. ** Bad. † Fair.

Group VIII

Built by Brown, Quincy, 1892–1893; 100 by 24 by 4½ feet; Douglas Fir. Cost, $1,600 each.

No.	Repairs to Barges 1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	Total
153...	...	$31	$ 50	$ 7	$10	$ 61	$162	$312	...	$230	...	$ 86	$ 54	$33	$ 97	**	$1,133
154...	...	33	3	4	8	124	23	165	$153	101	$78	400	165	...	***	...	1,257
156...	...	18	2	...	92	*	...	...	...	...	...	...	...	...	...	...	....
157...	...	18	35	25	8	121	23	151	144	70	78	400	165	85	60	***	1,833
158...	...	70	2	3	49	156	18	150	147	78	78	397	290	9	7	***	1,454
159...	...	34	2	4	14	156	23	168	192	51	78	400	231	5	...	***	1,358
160...	...	34	2	10	14	153	23	159	126	76	78	397	200	5	26	***	1,294
161...	...	18	8	...	14	63	160	317	...	182	...	96	69	41	118	***	1,086
162...	...	17	159	...	...	74	144	380	...	211	...	104	73	57	124	***	1,343

* Wrecked. ** Rebuilt. *** Condemned.
Several of these barges were partly rebuilt and all had new decks. No. 153 rebuilt and in use, 1911.

Group IX

Built by United States at Keokuk, 1894; 110 by 24 by 5 feet; Douglas Fir. Cost, $1,400 each.

No.	Repairs to Barges 1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	Total
4	$20	$88	...	$ 2	$17	*$327	...	$ 74	...	$173	$ 33	$ 35	$ 79	**	...	$ 848
7	...	...	...	33	72	169	$ 3	*200	...	178	39	19	89	**	...	802
70	...	...	...	...	...	24	49	*337	$41	250	...	99	116	***	...	916
179	...	1	$2	...	44	21	13	*362	41	250	90	100	97	$47	****	1,068
180	...	1	2	23	5	16	42	*375	41	50	127	86	87	****	...	854
181	...	1	2	22	5	33	49	*325	41	250	98	104	59	10	***	999

* New deck and partly rebuilt. ** Rebuilt. *** Bad. **** Condemned.

Group X

Built by United States at Le Claire (C. W. D.), 1885; 120 by 20 by 5 feet. White pine with oak bottom, planked fore and aft. Cost, $1,300 each.

No.	Repairs to Barges 1885–90	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	Total
97	....	$ 90	$159	$ 47	*$1,229	$172	...	...	$101	...	$100	$29	$308	$80	$391	$105	$49	...	**	$2,860
98	....	132	16	10	....	*901	...	...	...	$106	216	5	160	...	225	27	18	$95	**	1,911
99	....	64	...	64	*949	18	...	...	34	114	355	...	206	9	...	31	18	115	**	1,977
100	....	83	...	222	54	...	...	$ 14	70	...	...	**	...	...	...	...	...	...	..	443
101	....	171	159	31	*1,082	*394	...	30	6	74	46	...	217	82	365	165	49	...	**	2,871
102	....	139	159	31	*1,034	...	...	210	6	6	34	...	218	79	384	178	49	...	**	2,523

* Rebuilt; life 21 years, once rebuilt. ** Condemned.
These were the best barges used in this improvement. Cost of repairs and building large, but justifiable.

Recapitulation. Scow Barges

Group	Number Barges	Dimensions Feet	Material	Cost Each	Years in Service Max.	Years in Service Min.	Years in Service Av.	Repairs Max.	Repairs Min.	Repairs Av.	Remarks
I	8	100 x 20 x 4	White pine.....	$ 770	8	6	7¼	$ 681	$ 91	$ 367	Light loads for the last year or two.
II	8	100 x 20 x 4	White pine.....	770	8	6	7½	561	134	277	Do.
III	8	100 x 20 x 4	Fir	806	16	13	14¼	1,323	628	1,044	Wrecked barge omitted. Barges show great vitality. Principal repairs, new decks and calking.
IV	6	100 x 20 x 4	Fir	800	17	15	16⅔	881	564	719	Great longevity, small repairs, all but two in fair condition, 1911
V	3	100 x 20 x 4	Fir	806	14	12	13	958	693	825	Not so satisfactory as III and IV.
VI	5	100 x 20 x 4	Fir and pine...	790	15	11	14	1,789	517	1,316	Very large and apparently unjustifiable repairs in the last four years. Three still in use and in fair condition.
VII	9	100 x 20 x 4¼	Fir	768	15	9	12½	1,783	349	1,071	Built U. S. Three in fair condition, 1911; large repairs.
VIII	8	110 x 24 x 4½	Fir	1,600	15	14	15	1,454	1,086	1,282	Wrecked barge omitted; long life with moderate repairs.
IX	6	110 x 24 x 5	Fir	1,400	14	13	13⅓	1,068	802	913	Two of this group rebuilt in 1908. Built U. S.; good life, small repairs.
X	6	120 x 20 x 5	Pine with oak bottom	1,300	22	15	21	2,871	443	2,098	All but one rebuilt.

Dump Scows

Dimensions, 73 by 18 feet; eight pockets. Nos. 1 to 6, oak; Nos. 7 to 12, mostly fir.

No.	When Built	Cost	Repairs To 1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901				Total Repairs	Good Life
1.....	1885	$1,637	$690	$317	$98	Bad	Bad	Cond.	...	...	...	...	...				$1,105	8
2.....	1885	1,637	690	428	32	52	Bad	Cond.	...	...	...	...	...				1,202	8
3.....	1885	1,637	590	93	4	109	Bad	Cond.	...	...	...	...	...				796	8
4.....	1885	1,637	98	545	35	104	Bad	Cond.	...	...	...	...	...				782	8
5.....	1885	1,637	111	578	31	77	*1,359	.....	...	138	...	...	Cond.				2,294	9
6.....	1885	1,637	555	149	30	Bad	Bad	Cond.	...	...	...	...	...				734	8
			1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910		
7.....	1896	1,192	30	8	27	115	220	150	*687	2	43	7	116	209	388	Cond.	2,102	6
8.....	1896	1,187	30	19	52	63	217	171	Cond.	...	...	...	...	...	...	...	552	6
9.....	1896	1,625	4	9	49	115	79	150	Cond.	...	...	...	...	...	...	...	406	6
10.....	1896	1,651	3	6	36	79	215	152	102	171	110	Bad	Cond.	...	...	...	874	9
11.....	1896	1,651	...	...	...	2	28	338	*625	388	65	Bad	Cond.	...	...	...	1,446	9
12.....	1896	1,636	...	...	...	...	28	329	*664	401	107	Bad	Cond.	...	...	...	1,529	9

* Rebuilt. The rebuilding of No. 5 was not good policy. Nos. 7 and 8 used old irons. So much money for repairs on Nos. 11 and 12, 1902 to 1905, seems injudicious. The dump scows are of the usual side pocket type.

135 x 26 x 5½-ft., were built on the Ohio River, three by Howard, of Jeffersonville, Ind., and three by Cutting, of Metropolis, Ill. These barges, numbered 60–62 and 88–90, were built in 1882 at $3,500 each, and were not condemned until 1901, but for five or six years previous the repairs were very heavy. These barges were in use eighteen years.

Steel Barges. Fourteen steel barges built for use on government work on the Mississippi River and placed in commission in 1912 are described in *Engineering and Contracting*, April 24, 1912. These barges cost $9,300 each, have a capacity of about 400 tons, and an estimated life of over twenty years They are used in conjunction with creosoted wood barges of about the same capacity, but costing half as much and with an estimated life of ten years. It will be well to compare these estimates of life with those of Mr. Hageboeck, described later

The steel barges are 120 ft. long, 30 ft beam, 7 ft. 4 in. deep at center of hold and 7 ft. at sides. They are of steel throughout, flat bottomed, with rounded knuckles, wall sided, symmetrical about center line, with a rake 15 ft. long, a sheer 12 in. high at each end, and a crown of beam 4 in. There are four transverse water-tight bulkheads, and one non-water-tight longitudinal bulkhead over the center line, and two longitudinal trusses.

Untreated Wood, Treated Wood and Steel Compared. Mr. A. C. Hageboeck, United States Inspector at Rock Island, Ill, in a paper presented to the American Wood Preservers' Association, and reprinted in *Engineering and Contracting*, April 24, 1912, gives the comparative costs of barges of treated and untreated timber and of steel He states that the life of untreated yellow pine barges is difficult to determine due to lack of accurate records, but that a barge containing a minimum proportion of sappy timber is past economical repairs at the end of ten years. Pressure-treated yellow pine barges have been used for twelve years and are good to day for an additional life of ten years. It is necessary to recalk the barges after two years' service. The original cost of untreated barges, 120 x 30 x 6 ft. built in the early nineties was about $3,000, and the cost during ten years averaged $2,006.61 per barge. The original cost of pressure-treated yellow pine barges of the same size was $4,000, and the cost of repairs averaged $557.35.

The table on page 66 compares the two kinds of barges.

Repairs to untreated fir barges are mainly due to decay and not to abrasions. The life of barges of this wood used on the upper Mississippi has been from ten to seventeen years, averaging fifteen. The cost of repairs is slight up to the sixth or

Comparative Annual Cost of Treated and Untreated Yellow Pine Barges

120 Ft. x 30 Ft. x 6 Ft.

	Untreated Barges, 10 Years Old	Treated Barges, 9 Years Old
Original cost	$3,093.39	$4,000.00
Cost of repairs	2,006.61	557.35
Total cost	$5,100.00	$4,557.35
Value of barges today	....	$3,600.00
Cost of barges during total periods	$5,100.00	957.35
Annual cost per barge	510.00	106.00
Annual saving in favor of creosoted barge	....	404.00

seventh year, at which period $200 to $300 is spent for extensive repairs. After that time repairs average $75 per year until the tenth or twelfth year, when extensive repairs are again required and the barges have to be taken from rock work and placed in the brush carrying service. The life of treated fir barges is estimated at twenty years with slight repairs.

The following table is based on government freight rates on timber, and for commercial comparison, $10 per barge should be added to the yearly cost.

Comparative Cost of Light Draft Barges Built of Various Kinds of Material

100 Ft. x 20 Ft. x 4 Ft. 7 in.

	Douglas Fir Untr'd	Douglas Fir Tr'd 10 lb.	Yellow Pine Untr'd	Yellow Pine Tr'd 14 lb.	Steel
	15 year life	20 year life	15 year life	22 year life	25 year life
Original cost	$1,200	$1,500	$1,300	$1,650	$4,000
Total repairs	1,094	400	1,094	700	400
Interest at 5% on cost	900	1,500	975	1,815	5,000
Interest at 5% on repairs	341	125	341	125	125
Total cost	$3,535	$3,525	$3,710	$4,290	$9,525
Annual cost per barge	$236	$177	$247	$195	$381
Annual saving in favor of creosoted fir barge	59	....	70	18	204

Further data on the cost of barges are given by Mr. John L. Taylor in *Engineering News*, September 26, 1912, in which he takes exception to the price of steel barges given by Mr. Hageboeck above. He states that the following is an abstract of proposals for furnishing two gravel barges for Dam No. 28, Ohio River, opened on November 23, 1911:

Barges 100 Ft. x 22 Ft. x 5 Ft.

Bidder No.	Rate per barge	Amount	Material
1	$3,680	$7,340	Untreated wood
2	2,950	5,900	Untreated wood
3	4.350	8,700	Steel
4	3,870	7,740	Untreated wood
5	3,050	6,100	Untreated wood
6	3,620	7,240	Untreated wood

The above shows a ratio between the cost of a steel barge and a wooden barge of 1.47 to 1 in comparing the lowest price for a wooden barge, and 1.27 to 1 in comparing the average price of wooden barges.

Bids opened on January 24, 1912, for two dump scows for the same work were as follows:

Barges 80 Ft. x 21 Ft. x 6 Ft. 4 ins.

Bidder No.	Rate per barge	Amount	Material
1	$6,490	$12,980	Untreated wood
2	6,565	13,130	Untreated wood
3	5,895	11,790	Untreated wood
4	6,700	13,400	Steel

The above shows a ratio between the price of steel and lowest price of wood barges to be 1 14 to 1 and between the price of steel and average price of wood barges to be 1.06 to 1.

Bids opened October 7, 1910, at St. Louis, Mo., resulted as follows:

Flat Barges, 55 Ft. x 16 Ft. x 3 Ft.

Bid No. 1, lowest bid for steel flat boats	$1,725 each
Bid No. 2, lowest bid for wooden flat boats	1,223 each

The cost ratio is 1.41 to 1.

Miscellaneous Boats. Mr. C. W. Dunham in *Professional Memoirs*, reprinted in *Engineering and Contracting*, gives the following information in regard to quarter boats of pine or fir:

Quarter Boats. The quarter boats used in this improvement, in which category may be included office-boats and inspection boats, have been very numerous and always long lived, because it has been advisable to rebuild hulls or provide new ones on account of the cabins, which do not decay or wear out. The dimensions and design of these boats have varied — in fact, it is believed that there are hardly any two alike.

Building boats have not been standardized, although those recently built are quite similar. Many of these boats were adapted from ordinary barges. They are used in building dams, being suspended along the line of the dam; the brush and rock barges are handled with their power.

QUARTER BOATS. HULL, PINE OR FIR. CABINS, PINE

No.	When built	Dimensions Hull, ft.	Dimensions Cabin, ft.	Cost with outfit	Material of hull	Remarks	Repairs and Outfit to Dec. 31, 1910	Condition, Dec. 31, 1910	Life yrs.
75	1882	75 x 20 x 3	*60	†$ 700	Pine	1882–1891 no repairs; hull rebuilt 1894 and 1907; large repairs 1898 and 1909.	$4,319	Fair	28
118	1891	70 x 20 x 3	*55	1,414	Pine	Large repairs 1897, 1899, 1902, 1905, 1907; new hull 1910, fir.	3,205	Good	19
47	1894	75 x 20 x 3	60 x 19	1,561	Pine	Nominal repairs to 1908 when hull was rebuilt.	1,628	Good	16
71	1894	75 x 20 x 3	60 x 19	1,138	Pine	Nominal repairs to 1904; large repairs 1905–1907; hull rebuilt 1909.	2,763	Good	16
183	1895	100 x 20 x 3	80	2,698	Pine	Nominal repairs to 1909, when hull was rebuilt.	3,199	Good	15
184	1895	60 x 18 x 3	45	871	Pine	Nominal repairs to 1910, when hull was rebuilt.	1,558	Good	15
202	1895	70 x 20 x 3	55	1,328	Pine	Nominal repairs to 1907, when hull was rebuilt.	2,269	Fair	15
11	1893	75 x 20 x 3	60 x 19	1,648	Pine	Nominal repairs to 1910, when hull was rebuilt.	2,206	Good	16
65	1893	40 x 16 x 2	30 x 16	416	Pine	Nominal repairs to 1907, when hull was rebuilt.	698	Good	16
94	1884	60 x 16 x 3	......	250	Pine	Small repairs to 1902, when hull was rebuilt; new hull in 1910.	1,429	Fair	26
91	1884	60 x 16 x 3	......	452	Pine	Small repairs to 1895, when hull was rebuilt. New hull in 1905.	1,400	Fair	26
121	1892	52 x 16 x 2½	40 x 12	430	Pine	Small repairs to 1903, when hull was rebuilt; new hull in 1910.	1,197	Good	28
122	1892	52 x 16 x 2½	40 x 12	430	Pine	Small repairs to 1903, when hull was rebuilt; new hull in 1910.	1,198	Good	28
123	1892	52 x 16 x 2½	40 x 12	430	Pine	Small repairs to 1903, when hull was rebuilt; new hull in 1908	848	Fair	28
124	1892	52 x 16 x 2½	40 x 12	430	Pine	Small repairs to 1903, when hull was rebuilt; new hull in 1908.	1,027	Good	28

No.	When built	Dimensions Hull, ft.	Dimensions Cabin, ft.	Cost with outfit	Material of hull	Remarks	Repairs and Outfit to Dec. 31, 1910	Condition, Dec. 31, 1910	Life yrs.
20	1897	64 x 18 x 3	50 x 18	$1,452	Fir	Small repairs to 1905, when hull was rebuilt.	982	Good	13
67	1893	66 x 18 x 3	46 x 18	1,727	Pine	Small repairs to 1907, when hull was rebuilt.	2,831	Good	17
69	1893	50 x 16	38 x 16	607	Pine	Hull partly rebuilt in 1904; small repairs in other years.	994	Good	17

* A good part of the expense attached to these boats is in the renewal of outfit.
† The cost of No. 75 seems small, but it does not include outfit.

Building Boats

Nos. 36 and 38, Hand-Power Capstans; No. 64, Steam Power

No.	When built	Dimensions of hull, ft.	Material of Hull	Cost	Remarks	Condemned	Total Repairs	Good Life
36	1893	120 x 18 x 3	Pine	$1,385	Nominal repairs to hull and machinery to 1907.	1908	$ 975	14
38	1893	120 x 18 x 3	Pine	1,385	Nominal repairs to hull and machinery to 1902. Bad from 1903 to 1908.	1908	586	9
64	1895	160 x 26 x 4	Fir	3,786	Nominal repairs for four years; large repairs 1902 to 1908.	1908	2,709	13

Hulls of building boats were not rebuilt, the capstans, etc., being transferred to new and improved hulls.

BARS

Net prices for solid steel crowbars, lining bars, claw bars, and railroad tamping bars, are about as follows (1920):

	Per lb.
Crowbars	12 ct.
Lining bars	13 ct.
Claw bars, goose neck	14 ct.
Claw bars, with heel	14 ct.
Railroad tamping bars	12 ct.

BELTING FOR POWER PURPOSES

Flat Leather. Price per one inch width per running foot in cents. Single, 23 cents, double 47 cents. Weight 16 oz. to 1 sq. ft. in single ply.

Round Leather. Solid, price per running ft. in cents:

1/8 in. diameter	3.5 ct.
3/16 in. diameter	5
1/4 in. diameter	7
5/16 in. diameter	10.5
3/8 in. diameter	14.5

Cut lacings, bundles, price per 1/4-in. width per 100 ft., $1.90.

Rubber. Price per 1 in. width per running foot:

Ply	Smallest width in in.	Price per ft.
2	1	$0.118
3	1	.130
4	1	.156
5	1½	.293
6	2	.475
7	4	.935
8	6	1.580
9	6	1.790

Stitched Canvas. Price per 1 inch width per running foot:

Ply	Smallest width in in.	Price per ft.
4	1	$0.120
5	2	.294
6	2	.354
8	4	.888
10	12	3.080

Detachable Link Belts. Below is a table of various sizes of detachable link belt with prices, etc. Figure the working strain at one-tenth the ultimate strength for speeds of from 200

to 400 feet per minute. For lower speeds increase this by two-thirds. When a number of attachment links for fastening on buckets, etc., are used, add about 15% to cost of chain.

COST AND STRENGTH OF LINK BELT DETACHABLE CHAINS

Chain No.	Price per ft.	No. of links in 10 ft.	Width in inches	Ultimate strength
25	$0.12	133	3/4	700
32	.18	104	15/16	1,100
33	.12	86	15/16	1,190
34	.14	86	1 1/16	1,300
35	.14	74	1 1/8	1,200
42	.15	88	1 3/16	1,500
45	.13	74	1 1/4	1,600
51	.18	104	1 1/8	1,900
52	.18	80	1 7/16	2,300
55	.16	74	1 5/16	2,200
57	.19	52	1 11/16	2,800
62	.22	73	1 9/16	3,100
66	.23	60	1 3/4	2,600
67	.23	52	1 5/16	3,300
75	.22	46	2	4,000
77	.26	52	2 1/8	3,600
78	.35	46	2 1/2	4,900
83	.41	30	2 15/16	4,950
85	.46	30	3 13/16	7,600
88	.40	46	2 1/2	5,750
93	.45	30	2 7/8	7,500
95	.50	30	4 1/8	8,700
103	.58	39	3 1/16	9,600
105	.60	20	4 1/16	6,900
108	.62	25 1/2	4 5/8	9,900
110	.80	25 1/2	5 1/16	12,700
114	.88	37	3 5/16	11,000
122	1.03	20	5 1/2	15,000
124	.99	30	3 7/8	12,700
146	.90	20	5 1/4	14,000

SECTION 7

BENDING MACHINES

Hand bar bending machine capable of bending any size of bar from ¼ to 1½ in. round, square or deformed to any angle desired, weighs about 400 lb. for shipment and costs $100 f. o. b. Minnesota.

Stirrup and Column Stay Benders. A small bender designed so that a 45 degree turn of the lever will give a 90 degree bend to the bar costs $8.00. A larger, capable of bending round bars up to ⅞ in., costs $12. These benders may be mounted on a bench.

Bar crimpers designed for use on reinforced concrete construction to do miscellaneous bending work on the job, such as bending slab bars around elevator openings, stairways and beam bars that do not fit as calculated, etc., cost from $6 to $8. They are made in the following sizes ¾, ⅞, 1, 1⅛ and 1¼ inches and will bend bars their equal in size or smaller.

Another make of bar bender costs as follows f. o. b. Illinois.

Height of dies, in.	Weight in lb.	Price
2	280	$50
3	290	53
5	300	55

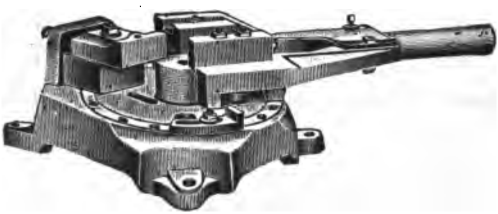


Fig. 26. Bar Bender.

This machine will bend round, square, and twisted bars cold up to 1¼ in. and hot up to 2 in. The 2-in. die will bend flats ½ by 2 cold, and 1 by 2 hot; the 3-in. die will bend flats

½ by 3 inches cold and 1 by 3 hot; the 5-in. die will bend flats ½ by 4 cold and 1 by 5 hot. Special dies for this machine may be had.

An angle bender fitted with special dies for making stirrups and hangers for beams, anchors for concrete work, etc., weighs about 135 lb. and is priced at $32.50. Special dies of various sizes may be had for this machine at from $2.50 to $5.

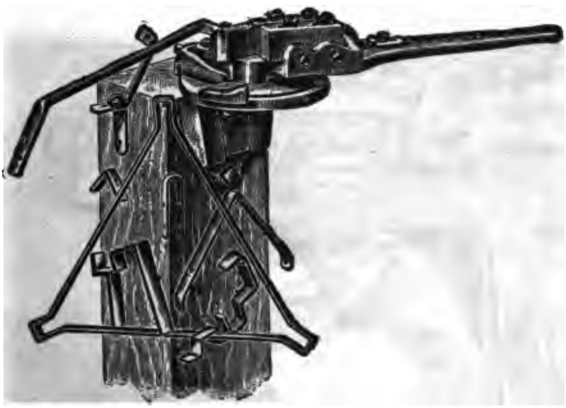


Fig. 27. Angle Bender.

A bar bending machine particularly designed for bending stirrups is illustrated in Fig. 28. The Turner Construction Company states that a metallic lather, in eight hours, would bend from 300 to 500 stirrups per day, while with this bender they found it easily possible to bend from 1,200 to 2,000 stirrups per day. The price of the machine is about $90, f. o. b. New York.

Truck Mounted, Power Operated Bender for Reinforcing Rods. A bar bending machine equipped either with gasoline engine or electric motor, and mounted on wheels for transportation by team is illustrated by figure 29. This machine is designed to bend any size or shape of reinforcing rod that is likely to be used in building operations. It will bend rods up to 1½ in. diameter, round, square, or deformed, and is also provided with an attachment at the rear by means of which spirals or rings of any diameter from 10 in. up may be formed. It is, for example, used frequently for turning rings for column head reinforcement used in the Turner Mushroom system of reinforcing.

The operation is simple, the action of the bending member being controlled by a lever at the rear of the machine.

The machine is fitted with gages, scaled in feet and inches, so that no marking of the rods is necessary, and so that height of truss and angle of bend can be set. Wagon trucks and steel wheels are provided so that the machine may be readily moved from place to place. Each rear wheel is provided with a square steel shaft which fits a hollow square axle so that it can be readily removed, should it be desired to have greater freedom of movement about the machine by having the wheels out of the way. The front truck can be turned under the machine.

Fig. 28.

The total cost of operating this machine per ten hour day is given as follows:

Labor (3 men, one at 30, two at 25 ct. per hr.)	$8.00
Gasoline (3 gal.) and oil	.40
Interest and depreciation	.35
Total	$8.75

One man is required to direct the work and operate the machine, and two men to handle the steel. The manufacturer's statement as to performance is one ton per hour, average output, at a cost of $1.00 per ton, but this output has frequently been exceeded at a correspondingly lower cost. The best achievement has been 39 tons in 9 hours at a cost of 22 cts. per ton.

This machine equipped with a gasoline engine, mounted on

trucks complete, weighs approximately 2,700 lb. for shipment and costs $900 f. o. b. Minnesota.

Home Made Bench for Bending Reinforcing Bars. Mr. E. O. Keator in *Engineering and Contracting*, June 14, 1911, describes

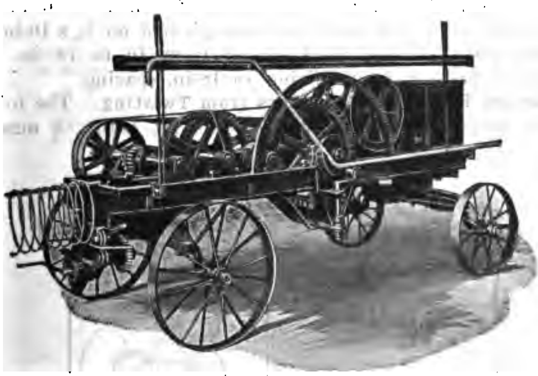


Fig. 29. Truck Mounted Power Operated Reinforcing Bar Bender.

a home made bench for bending reinforcing bars. It is illustrated by Fig. 30. The bench proper is 30 in. high and 5 ft. square on top and cost about $5 for labor to make, using second hand lumber. The bending device consists of two stationary sheaves

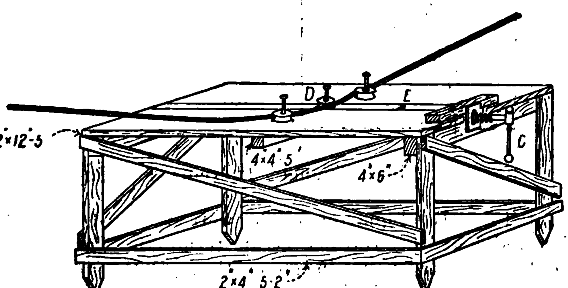


Fig. 30. Home Made Bench for Bending Reinforcing Bars.

and a movable sheave *D* mounted on a sliding strip operated by a screw *C*. The bar is inserted between the sheaves as shown and a man operates the screw *C*, thus moving the sheave *D* to produce the bend. The principle of operation as will be seen is that

of the familiar roller rail bender. A scale on the slide *E* indicates the travel required to produce corresponding bends. The bench as illustrated was used to bend the steel for sewers and a standpipe. It cost $1 per ton to bend ½-in. steel for an egg-shaped sewer. The sheaves used were taken from 6-in. double blocks used on the job and they were pivoted on ⅞ x 10-in. bolts. The stationary sheaves were spaced from 10 to 18 in. apart; the heavier bars, ⅛-in. requiring an 18-in. spacing.

Device on Bender to Keep Bars from Twisting. The following is taken from *Engineering Record*, Jan. 29, 1916. A number of

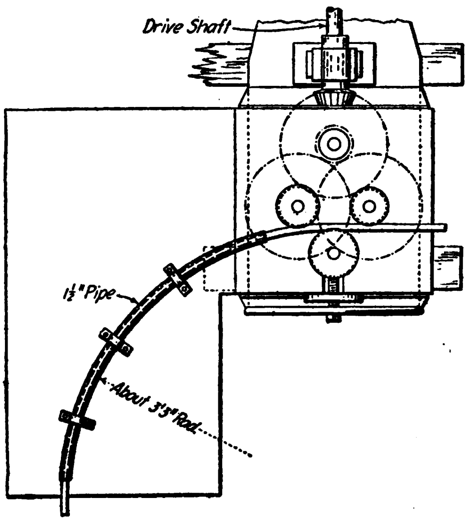


Fig. 31. Pipe "Tunnel" Prevents Twisting.

bars bent to a three-quarter circle were required in building the pier walls at the Halifax ocean terminal. The bars were light and would twist up in going through the rolls, and so acquire curves in several different planes. To overcome this and hold the bars flat on the table a pipe "tunnel" for the bent end of the bar to feed through was made of a piece of 1½-in. pipe. This was bent to a quarter circle and clamped down to the bending table on the circumference of a circle passing through the rolls. Fig. 31 illustrates this device.

Pipe Bending Machines. The following gives various sizes

of pipe bending machines together with the shipping weights and prices. The hand power machine is illustrated by Fig. 32.

PIPE BENDING MACHINES

(Without power)

Size pipe in inches	Approximate shipping weight in lb.	Price f. o. b. factory
⅛–1	160	$ 95
⅜–2	625	350
2½–3½	2450	650
4 –6	9000	2,350

(With power)

Size pipe in inches	Approximate shipping weight in lb.	Price f. o. b. factory
1¼–4	3500	2,000
3 –8	8000	3,500

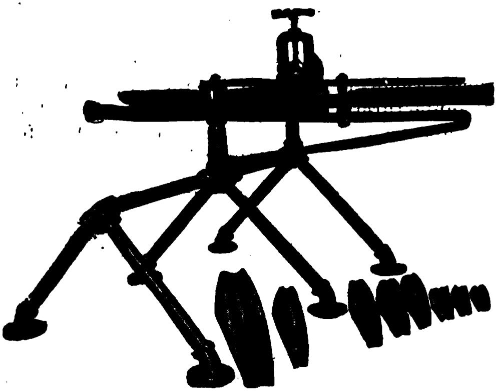


Fig. 32. Pipe Bending Machine.

A hand power machine of this type is stated to make a 90 deg. cold bend in a 6-in. iron pipe in less than 10 minutes at a labor cost of about $1.50. The bender consists of a circular head, which is supported by an upright and from which arms extend to carry the bending shoe and a toggle jointed lever. In operation the pipe is placed behind the head and the bending shoe and the pressure applied by moving the lever. In making a 6-in. bend, six laborers handled the lever.

SECTION 8

BINS

Portable Bins

Capacity in tons	Approximate shipping weight in lb.	Price f. o. b. factory
15	6,600	$430
20	7,700	550
30	10,450	750
40	14,300	900

Gravel screens for the above 15 and 20 ton sizes, 30-in. dia. by 9 ft. long, weigh about 1,000 lb. for shipment and cost $200 f. o. b. manufacturers' works. Screens for the 30 and 40 ton sizes, 30-in. dia. by 12 ft. long, weigh about 1,300 lb. for shipment and cost $270 f. o. b. manufacturers' works.

Fig. 33. 20 Ton Portable Bin. Screen in Position for Operation.

Portable Bins for Concrete Aggregates. A portable storage system for handling cement, sand, gravel and crushed stone is illustrated by Fig. 34 and consists of a number of bins into which the materials are deposited by a bucket elevator. These bins are built so that no danger of damage from rain exists. The capacity of the bins is one carload or more, and the aggregates are fed by gravity to the mixer below. For batch mixing, measuring devices can be fitted to the chutes or the materials can be directly spouted into the hopper.. For continuous mixing, automatic feeding devices can be attached to spouts, regulated to deliver varying amounts from the different bins at the same time.

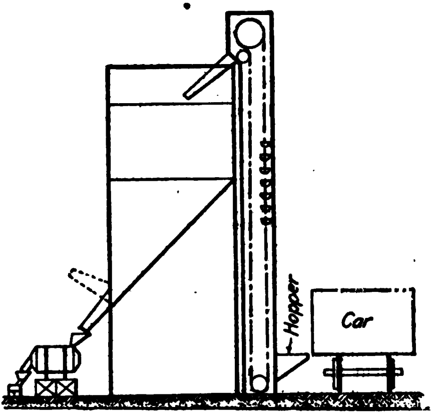


Fig. 34. Portable Bin for Concrete Aggregates.

By this arrangement maximum capacity can be reached, as the unloading from cars can be accomplished at the most convenient time and a large supply of material is constantly on hand and available by operating a lever. After finishing one job the equipment can be taken down, shipped to another point and quickly reassembled. The machinery can be operated by motor, gas or steam engine or any other available power. These storage systems can be built all steel or all wood, or a combination of steel and wood.

SECTION 9

BLACKSMITH SHOP OUTFIT

Tools necessary for a blacksmith shop for ordinary drill and general repair work are as follows:

1	Anvil, 130 lb.	$ 13.00
3	Augers, ship, 1, 1½, 2 in.	7.20
2	Bevels, universal	3.00
1	Brace and 13 auger bits, ¼–1 in., in canvas roll	7.50
4	Spring calipers	6.00
6	Chisels, cold, 12 lb. at 42 ct.	5.04
4	Chisels, hot, 8 lb. at 42 ct.	3.36
1	Cutter for pipe up to 3 in.	10.00
1	Drill, post, hand power up to 1½ in.	17.50
1	Drill, breast	3 00
12	Straight shank twist drills, assorted sizes to ½ in.	5.00
6	Drill dollies	15.00
12	Files, assorted, at $8 per doz. up to 12 in.	8.00
12	Files, flat	8.00
12	Files, rasps	16.00
1	Forge, with hand geared blower and hood	27.00
1	Grindstone, foot power	6 20
3	Hammers, blacksmith	3 60
4	Hardies, at 42 ct.	1.68
2	Pails, at 80 ct.	1.60
1	Rule, 6 ft. folding	.50
1	Saw, crosscut hand, 26 in.	1.85
2	Saws, hack, at $1.25	2.50
1	Sledge, double face, 5 lb.	1.50
2	Sledges, double face, 7 lb.	4.10
1	Sledge, cross pin, 5 lb.	1.50
2	Squares, at $2.00	4.00
1	Stock and eight dies for ½ in. to 2 in. pipe	21.00
8	Swages, bottom, 1 lb. each	3.20
8	Swages, top, 1 lb. each	3.20
1	Taps and dies, set, 5 sizes, machine threads	18.00
9	Tongs, assorted	9.00
1	Vise, blacksmith's leg	26.00
1	Vise, hinged for pipe up to 3 in.	[illegible]
		$274.03

SECTION 10

BLASTING MACHINES AND SUPPLIES

Blasting by electricity is the most effective and economical system. It surpasses all others in safety, certainty and in results. By this system it is possible to fire two or more charges simultaneously.

The equipment necessary for electric blasting is as follows:

Electric blasting caps.
Connecting wire
Leading wire
Blasting machine.

Blasting Machines

The following is the cost of blasting machines operated by pushing down. The pocket size is operated by turning a handle.

Size of machine	Maximum capacity	Used for	Weight in lb.	Price
Pocket	3	Stumping and boulder	4½	$21.00
2	10	Small blasts	15	17.50
3	30	General work	25	25.00
4	60	Large blasts	42	40.00
5	100	Large blasts	53	100.00
6	150	Large blasts	37	140.00

BLASTING SUPPLIES

(See also Explosives)

Blasters Thawing Kettles

Capacity	Approximate shipping weight in lb.	Price
30	15	$ 8.50
60	20	10.50

Blasting Augers

Augers may be conveniently used to bore holes for inserting dynamite under tree stumps, etc. They cost as follows:

	Inches	List price
*Dirt	1½	$1.25
*Dirt	2	1.35
*Dirt	2½	1.50
Wood	1½	1.75
Wood	2	2.25
Wood	2½	2.75
Auger handles	...	1.25

* Without handles.

Blasting Caps

Number 6 caps are strong detonators. No. 8 are nearly double the strength of No. 6. The following are prices per 1,000.

Number of caps in cases	Price Number 6	Price Number 8
500	$22.10	$34.60
1000	21.70	34.20
2000	21.60	34.10
3000	21.60	34.10
5000	21.50	34.00
10000	21.60	34.00

Discounts to apply to the above are as follows:

In lots of less than 1000	10% f. o. b. factory or distributing point
In lots of 1000 or over	15% f. o. b. factory or distributing point
In lots of 20000 or over	25% nearest R.R. station to destination

Electric Blasting Caps

The following are the prices of electric blasting caps per 100.

Length of wire in ft.	Price Number 6	Price Number 8
4	$ 9.00	$11.00
6	10.25	12.25
8	11.50	13.50
10	12.75	14.75
12	14.00	16.00
16	16.50	18.50
20	19.00	21.00

The same discounts apply to these as to the above.
Longer lengths (made to order) $1.50 for each additional 2 ft.
Waterproof electric caps cost about 30% more than the above.
Electric caps are packed as follows:

Length in ft.	Quantity per case	Gross lb.
4	500	25
8	500	38
12	500	53
16	500	66
20	250	47

Blasting Fuse

Fuse may be divided into four classes according to the class of work it is intended for. There are many kinds for each class, the following being of the plain finished varieties.

Kind of fuse and use	Price per 1000 ft.
Cotton, for use in dry work only, very pliable	$ 9.85
Single Tape, for use in damp work	10.50
Double Tape, for use in wet work	13.15
Triple Tape, for use in very wet work where exposed to rough treatment	15.00

Discounts to apply to the above are as follows:

In lots of less than 1000 ft.	10% f. o. b. Connecticut
In lots to 6000 ft.	15% f. o. b. Connecticut
In lots to 30000 ft.	20% f. o. b. Connecticut
In lots of less than 1000 ft.	7½% f. o. b. distributing point
In lots to 6000 ft.	12½% f. o. b. distributing point
In lots to 30000 ft	17½% f. o. b. distributing point

Approximate weights of packages of 1,000 ft. in 50-ft. lengths are 13 lb. for cotton and 23 lb. for the others.

Fuse should be stored in a cool, dry place and in handling care should be taken not to kink it.

Blasting Wire

Connecting wire. No. 20 B & S gauge and No. 21 on 1-lb. and 2-lb. spools.

Leading wire. No. 14 B & S both single and duplex in 200, 250, 300 and 500 ft. coils.

Leading wire reels $4.00

The price of wire varies with the locality and the market, but is about as follows:

Connecting wire No. 20	$0.59 per lb.
Connecting wire No. 21	.64 per lb.
Leading wire, single No. 14	.60 per lb.
Leading wire, duplex No. 14	.61 per lb.

Blasting Mats

Mr. H. P. Gillette, in "Rock Excavation," says:

"**Use of a Blasting Mat.** For preventing accidents due to flying rocks, all blasts in cities should be covered either with timbers or with a blasting mat. This should be done to avoid suits for damages, regardless of city ordinances. A blasting mat is readily made by weaving together old hemp ropes, 1½ in. diameter or larger. To make such a mat, support two lengths of 1-in. gas pipe parallel with one another and as many feet apart as the width of the mat is to be. Fasten one end of the rope to one end of the pipe; carry the rope across and loop it over the other pipe; bring it back around the first pipe; and so on until a sufficient number of close parallel strands of the rope have been laid to make a mat as long as desired. Starting with another rope, weave it over and under, like the strands in a cane-seated chair, until a mat of criss-cross ropes is made. Such a mat,

weighted down with a few heavy timbers, will effectually prevent small fragments from flying at the time of blasting. The mat and its ballast may be hurled into the air several feet, upon blasting; but it will serve its purpose by stopping the small pieces of rock which are so dangerous even where light blasts are fired. The mat should be laid directly upon the rock. Such a

Fig. 35. Blasting Mat.

mat will save a great deal of labor involved in laying a grillage of timbers over a trench. It will also make it unnecessary for the blasters to stand far from the blast when firing."

Manufactured mats cost, for 1 in. dia. rope, $1.60 per sq. ft. f. o. b. New York. These are furnished with a loop on each corner and binding on the sides. See Fig. 35.

SECTION 11

BLOCKS

Wrought Iron Gin Blocks for wire rope with stiff swivel hooks and beckets may be had in diameters of from 10 to 18 in. The single blocks cost from $12 to $24, the double from $19 to $33, and the triple from $30 to $55.

Wrought iron blocks for wire rope, heavy pattern, are made from 6 to 18-in. sheave diameters. The iron bushed type single, cost from $10 to $36, double from $15 to $50, and triple from $22 to $65. The self-lubricating bronze bushed blocks cost about 12% more.

Steel derrick and hoisting blocks for wire rope are made in sizes from 6 to 14-in., for diameter of from 1/4 to 1 in. They are self-lubricating with bronze bushings. The single cost from $6 to $16, the double from $8 to $25, and the triple from $12 to $40.

Wrought iron snatch blocks for wire rope in diameters of from 6 to 20 in. cost from $12 to $80 for the iron bushed. They will take rope from 3/8 to 1 1/2-in. in diameter.

Standard wood shell iron strapped blocks with sheaves in diameters of from 1 3/4-in. to 11-in. with common bushed sheaves, for rope of from 3/8 to 1 1/2-in., single block cost from $0.90 to $13, double block from $1.50 to $19, and triple from $2.25 to $25.

Metal blocks for manila rope from 1 3/8-in. dia. sheaves to 8 1/2-in. dia. sheaves cost, for single from $0.60 to $12, double blocks from $0.90 to $18, and triple from $2.25 to $25.

The above blocks are some of the more commonly used and the prices are approximate and to be used for estimating.

There are a great many different types and sizes of blocks of which the above is a fairly representative list, but, owing to limited space, by no means complete.

SECTION 12

BLUE PRINT MACHINES

Continuous blue print machine of the horizontal type is illustrated by Fig. 36. It takes continuous rolls or cut sheets from 2 to 48 in. wide. The tracings may be delivered at will to the storage compartment or to the operator for reprinting.

Fig. 36. Horizontal Blue Print Machine.

This machine weighs about 450 lb. for shipment and may be had to operate on any current condition. The price for the standard speed is $285 and for the high speed $350 f. o b. factory.

Blue print frames, with pad and polished plate glass, cost as follows:

Fig. 37. Print Frame on Wheel Carriage

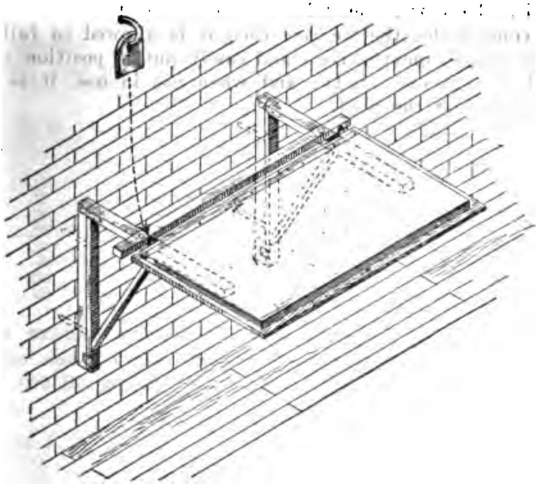


Fig. 38. Folding Rack for Blueprints.

	20x24	24x30	30x42	36x48	36x60	42x60	42x72
With oak frame	$26	$35	058	$79	$95	$110	$133
With hardwood frame	24	32	54	71	85	...	...
With wheeled carriage	..	79	108	134	151	169	200
With tilting carriage on rails for window	..	..	120	150	170	...	...
Same as above with revolving carriage	..	..	161	193	212	...	...

Mr. R. M. Jones in the *American Machinist*, Nov. 8, 1917, describes a folding rack for blueprints as follows:

In shops making a standard line of work, blueprints do not need to be taken to the machine, but must be readily accessible for reference. A convenient method of keeping them is in a folio, bound at the top and hung on the wall out of the way, offering little space for dust and dirt to collect. However, as it is handier to have the prints in a horizontal position when in use, the stand illustrated was made.

It consists of two braces hinged to two pieces fastened to the wall. A tie-bar is loosely bolted to the braces far enough from the wall to provide necessary room to allow prints to be folded back on the braces. The top of the folio, which has a stiff board back, is hinged to the tie-bar.

To extend the folio board, it is lifted to a horizontal position and moved to the right until the supporting braces come underneath it. To close, the folio is moved to the left until the braces come under the tie-bar; then it is allowed to fall. This makes a simple, inexpensive stand easily put in position (it may be worked with one hand); and when not in use, it is out of the way against the wall.

SECTION 13

BOILERS

Upright tubular boilers with full length tubes for 100 lb. steam pressure, fitted with injector and 10 ft. of smoke stack cost as follows:

H. P.	Weight in lb.	Price f. o. b. New York
4	1200	$ 331
6	1450	355
8	1800	415
10	2000	435
15	2700	530
20	3100	580
30	4100	767
40	6000	1,000
50	6700	1,090

Standard portable boilers for 100 lb. pressure, complete with fittings, injector, 10 ft. of suction hose, neck yoke, evener and whiffletrees, cost as follows:

H. P.	Weight in lb.	Price f. o. b. New York	
	Weight in lb.	Price On skids	On wheels
10	4300	$ 712	$ 962
15	5000	791	1,070
20	6000	882	1,172
25	6500	948	1,248
30	7400	1,043	1,353
40	9100	1,265	1,590
50	11000	1,566	1,910
60	13000	1,783	2,130

Return tubular portable boilers on skids complete with dry pipe under steam outlet, ashpit front with doors and bolts and injector, 100 lb. pressure, cost as follows:

H. P.	Weight in lb.	Price f. o. b. New York
15	7200	$1,030
20	8000	1,120
30	10100	1,375
40	13300	1,760
50	14400	1,890

The outside of the boiler should be kept dry at all times and the inside of it should be as nearly free from scale and rust as possible. Different kinds of water will have different effects upon the life of the boiler, and the results to be obtained from it. In a limestone country the boilers will scale rapidly. This scale is a poor conductor of heat and as soon as it reaches a considerable thickness will cause a marked decrease in a boiler's steaming efficiency. In alluvial country, where the water contains much vegetable and loamy matter, the boilers will gather an ac-

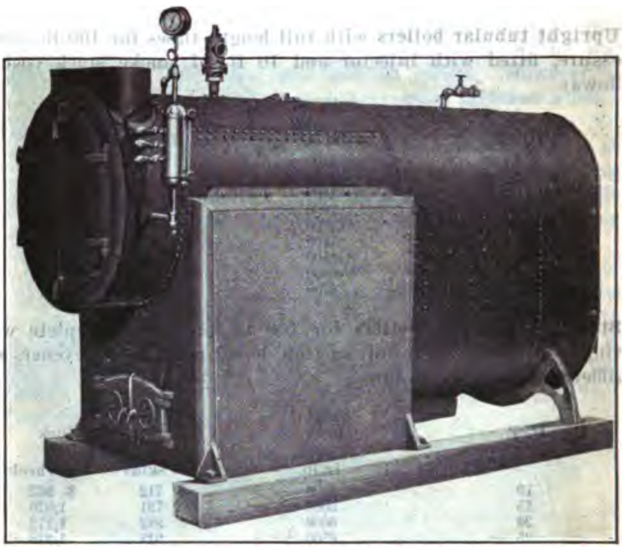


Fig. 39. Return Tubular Boiler on Skids.

cumulation of heavy mud and should be blown at least once each week.

Mr. John W. Alvord, of Chicago, gives a table showing the history of thirty-two horizontal tubular boilers used in water pumping stations in Illinois, Iowa and Michigan. The active life of these boilers was found to have ranged from six years for two boilers at Sterling, Ill., where artesian water was used, to twenty-three years for two boilers in Oskaloosa, Ia., where river water was used, the latter boilers being still in service. The average life of this group of thirty-two boilers was fifteen years.

This would indicate that the rate of depreciation on boilers should be 20% where artesian water is used, 10% where lake water is used and 5% where soft river water is used.

Estimating the Horsepower of Contractors' Boilers. A boiler is usually estimated to give one horsepower for every 10 sq. ft. of heating surface. Hence the horsepower of a vertical tubular boiler is found thus:

Rule: Divide the total heating surface of the tubes and fire box (expressed in square feet) by ten, and the quotient is the horsepower.

The square foot heating surface of a tube is quickly calculated by multiplying the length of the tube in feet by 0.26 and then multiplying by the outside diameter of the tube in inches. Since tubes are ordinarily 2 in., the total heating surface of the tubes is found by multiplying the number of tubes by their length in feet by 0.52; or, for all practical purposes, take half the product of the number of tubes by the length of tube in feet. To this heating surface of the tubes must be added the heating surface of the fire box, which is ascertained thus: Multiply the circumference of the fire box in feet by its height above the grate in feet and add the square foot area of the lower flue sheet.

The diameter of the fire box or furnace is usually 4 to 5 in. less than the outside diameter of the boiler. The height of the fire box is usually 2 to 2½ ft. The amount of coal required for a contractor's boiler is about 6 lbs. per horsepower per hour, or 60 lbs. per horsepower per day of ten hours. Nearly one gallon of water will be required for each pound of coal. About 2⅓ lb. of dry wood are equal to 1 lb. coal, or 2 cords of wood equal 1 ton of coal.

Boiler Room Tools

Length in ft.	Hoe	Slice bar	Price Clinker hook	Poker
6	$1.50	$1.20	$1.50	$1.00
8	2.25	1.90	2.30	1.65
10	3.85	3.80	3.60	2.50
12	5.75	5.50	5.50	3.50

Roller tube expanders, 1 in. to 4 in., $10 to $30.

SECTION 14

BRICK RATTLER

The city of Baltimore in 1909 installed a "rattler" for testing vitrified blocks. The machine is 28 in. in diameter, 20 in. long within heads. The barrel is a regular paragon of fourteen sides and contains about 12,018 cubic inches. It is driven by a 5 hp. single phase electric motor making 1,710 revolutions per minute. The speed was geared down at the "rattler" end of the belt to produce thirty revolutions per minute. The cost of the outfit and the expenditures during the first year were:

One vitrified block rattler with belt	$192.50
One 5 hp. motor	150.00
Cast steel shot	12.00
Freight and drayage	10.20
Building foundation and remodeling shed	53.32
One set scales	8.70
New cast-iron shot	10.20
One new pulley	5.20
One revolution counter	4.00
Electric installation	37.64
Electric company's connections	3.73
Electric current	5.69
	$493.18

SECTION 15

BUCKETS

Contractors' buckets are of two general types: (1) that which is filled by hand, or other agency outside itself, and (2) that which fills itself by digging into the material to be conveyed. The first type of bucket as used by contractors, is usually a dump bucket, and the bowl is cleared by either tilting it, or allowing a door or grate in the bottom to open, thereby releasing the material. The second type of bucket is usually either clamshell or orange peel, but is sometimes made in special shapes.

The following table gives the approximate weights of materials commonly handled with buckets:

Material	Weight per cu. yd., lb.
Dry sand	2,700
Wet sand	3,400
Loose earth	2,400
Wet clay	3,000
Anthracite coal	1,600
Bituminous coal	1,450
Crushed stone	3,000
Iron ore	4,200
Granulated slag	1,600
Gravel	3,000

Fig. 40. Bottom Dump Bucket.

Bottom dumping buckets similar to Fig. 40 cost as follows:

Capacity in cu. ft.	Approximate weight, lb.	Price
3	175	$ 90
7	360	112
10	450	132
12	500	146
14	575	168
18	650	182
21	745	196
27	850	210
34	1,025	256
41	1,150	280
54	1,650	370
63	1,700	392
67	1,775	406
75	2,070	420
85	2,300	454

Coal tubs similar to Fig. 41 cost as follows:

Capacity coal, tons	Cu. ft.	Weight in lb.	Price f. o. b. factory
1/8	5	150	$ 36
1/4	10	270	52
1/2	20	440	96
1	40	800	126
Long ton	45	825	134

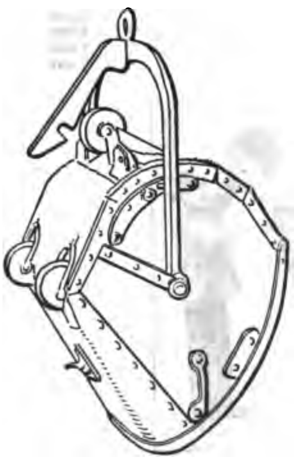


Fig. 41.

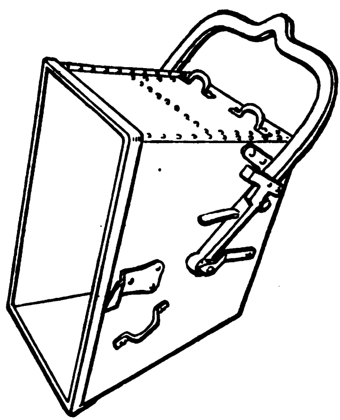


Fig. 42.

Contractors' tubs, Fig. 42 cost as follows:

Capacity cu. ft.	Length inches	Width inches	Depth inches	Price f. o. b. factory
3	26	28	15	$ 32
6	33	26	19	36
12	42	33	25	52
18	48	37	29	66
27	53	43	29	84
42	60	58	33	112

Contractors' and miners' round tubs, Fig. 43 cost as follows:

Capacity cu. ft.	Length inches	Width inches	Depth inches	Price
6	31	37	21	$ 32
14	44	49	25	56
21	48	56	30	72
27	50	60	34	88
42	58	71	40	120

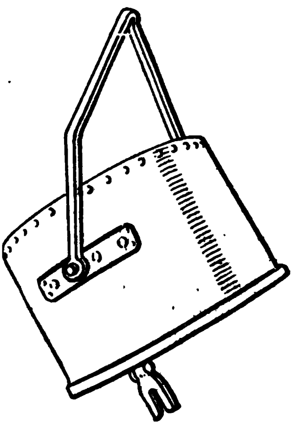


Fig. 43.

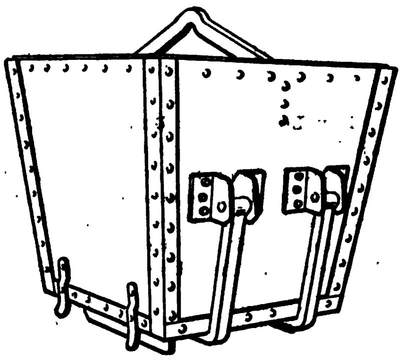


Fig. 44.

Bottom dump buckets, similar to Fig. 44 cost as follows:

Capacity, yds.	Top width	Bottom width	Depth	Price
½	31	25	30	$ 96
1	41	32	37	120
1½	46	35	42	160
2	51	39	45	200
3	61	48	48	300

Straight side self-dumping, self-righting tip bucket, which dumps itself under load when the catch is released and auto-

matically rights itself after the load is discharged, has a reinforced bottom and costs as follows:

Capacity, level full, cu. ft.	Net weight in pounds	Price f. o. b. factory
15	420	$130
22	636	145
28	696	155
36	800	175
45	1085	200

Center dump bucket for general use is built with the bottom of the bucket larger than the top so that no difficulty is met in dumping all kinds of material whether wet or hardened. The operating lever locks and unlocks the bucket automatically. This bucket is reinforced and stated to be practically grout tight.

Capacity in cu. ft.	Net weight in pounds	Price f. o. b. factory
15	661	$184
22	730	220
30	1069	250
36	1114	275
45	1442	300
54	1518	317
67	2000	360
75	2041	390

Tow Line Bottom Dump Bucket. This bucket is a controllable discharge bucket with all four sides tapering outward toward the bottom, making it larger at the bottom than at the top. It may be used to handle concrete of any consistency, aggregates, earth and rock. It is practically grout tight and is operated by two lines, and may be had with a double operating hook which brings the holding line and the operating line together in a unit.

Capacity in cu. ft.	Net weight in pounds	Price f. o. b. factory
15	597	$125
22	661	140
30	812	158
36	864	168
45	1002	195
54	1075	219
67	1530	280
75	1627	304

A double operating hook for the above is made in several sizes as follows:

For buckets' capacities	Capacity in tons	Price f. o. b. factory
15 and 22	2	$22
30 and 36	3	27
45 and 54	5	40
67 and 75	7	55

Controllable Form Buckets. These buckets are used for placing concrete in forms where a narrow controllable bottom discharge is advantageous (Fig. 45).

Capacity wet concrete, cu. ft.	Net weight in pounds	Price f. o. b. factory
12	525	$165
14	560	175
22	778	195
27	845	205
40	1039	230
54	1313	270

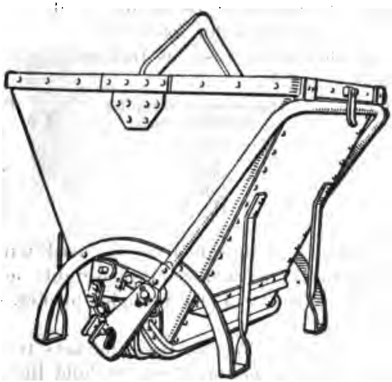


Fig. 45. Controllable Form Bucket.

Clam Shell Buckets

A strong, simple, clam shell bucket to operate on two hoisting cables costs as follows.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
¼	1320	$ 450
½	2300	550
¾	2650	625
1	3100	725
1¼	3600	950
1½	4100	1,100
1⅝	4650	1,300
2	5500	1,500

The above prices are for buckets without teeth. If teeth are wanted add from $35 to $60.

A more powerful bucket operating on two hoisting cables costs as follows:

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
½	3000	$ 800
¾	3200	975
1	4400	1,100
1¼	5600	1,200
1½	6000	1,250
2	7500	1,780
2½	9900	2,000
3	12000	2,300

The above prices are for buckets without teeth. Teeth are from $35 to $90 extra.

The above buckets arranged to be operated with a four part hoisting cable cost $50 more for each size.

A bucket of another make costs as follows:

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
¾	3350	$ 750
1	4100	900
1½	5900	1,150
2	8000	1,600
3	11500	2,550

The above buckets are designed to be used with a five part reeving when operated with a counterweight, and three part without the counterweight. Price includes bucket, complete, with teeth.

Equalizer bars may be added to these buckets to take two holding lines. These bars are mounted on the hold line pin at head of bucket and arranged either parallel or at right angles to hinge pin. These bars cost from $21 to $40 for the 18-in. size, $26 to $50 for the 24-in. size and from $39 to $75 for the 36-in. size.

Single line, automatic, clamshell buckets when operated by derricks may be used for handling sand, gravel, coal, etc., and excavating in loose soil. They may also be attached to portable cranes, steam shovels, and other single drum rigs without the necessity of additional drums. They may also be used on cable ways without any change in engines or lines. They cost as follows:

Capacity in cu. yd.	Complete weight in lb.	Price f. o. b. factory
¾	2600	$1,075
1	3850	1,350
1½	5200	1,700
1¾	5600	1,825
2	10000	3,100

Scraper clamshell buckets, for handling ore and extra hard, heavy material.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
1	3630	$ 682
1½	4510	780
2	5060	880
2½	6600	1,210
3	7600	1,400
4	9700	1,720
5	12000	2,140
7½	16000	2,930
10	20000	3,500

Fig. 46. Scraper Clamshell Bucket.

Orange Peel Buckets

Standard orange peel buckets are adapted to all classes of dredging and excavating. They are good all around digging buckets, and are sometimes used for handling ore.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
¼	1300	$ 420
½	2300	630
¾	3800	860
1	4800	970
1½	7100	1,260
2	9500	1,640
2½	10500	1,720
3	12000	1,880
4	15000	2,250
5	19000	2,800

Multi-power orange peel buckets are used for digging clay, compact sand, and other hard material, and are built about as the extra heavy standard, but differ in the closing mechanism, which in this case has twice the closing and half the lifting power.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
1	5200	$1,500
1½	9400	2,400
2	10500	2,800
2½	12000	3,100

Three-sided orange peel buckets are especially well adapted for the handling of boulders, broken rock, and other odd-shaped materials difficult to hold unless an even force is exerted on bearing part. This is possible with this three-bladed bucket.

An excellent illustration is given in Fig. 47 of what a three-bladed orange peel bucket can do. The points of three-bladed buckets coming in contact with a boulder or pile will either force it inside the bowl or will grasp the object as in the illustration in such a manner that the holding force will be positive and the strain equally divided.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. factory
1	5200	$1,500
1½	9100	2,200
2	10500	2,500
2½	12000	2,700

Fig. 47. Three Bladed Orange Peel Bucket.

Miniature Excavating Buckets. The following notes are from *Engineering Record*, Feb. 26, 1910.

In the special foundations of a part of the New York rapid transit subways and some adjacent buildings, about 350 cylindrical steel and concrete piles, about 14 in. in diameter and varying in length from 8 ft. under some buildings to 60 ft. under the subway, have been sunk through strata of earth, sand and gravel, interspersed with stones of considerable size. The piles were constructed by putting down a steel shell and then filling it

with concrete, but owing to the limited headroom and contracted working space none of the usual methods of placing concrete piles could be used. It was necessary to drive the $\frac{7}{16}$-in. steel casing in successive lengths, 2 ft. long and overlapping each other about a foot, by means of a hydraulic jack or drop hammer. This could be accomplished without much trouble by using

Fig. 48. Dwarf Bucket in Use.

a cap on top of the upper section of the casing to prevent injury to it, but the removal of the material inside the casing proved decidedly troublesome at first.

It was decided to use miniature orange peel buckets weighing about 28 lb. apiece. They were operated, like the ordinary sizes, with two lines, one at the head of the bucket and the other

attached to the bull wheel, which were carried up to the sheaves of a double block and managed by two men, one for each line, and removed all the material successfully.

This kind of excavating was necessarily conducted in a succession of stages. After the casing was forced down a few feet by the jack, the cap was lifted off, and the material taken out with a bucket. Other sections of the casing were then placed on top of those already sunk, and the driving was resumed until it was necessary to use the bucket again. If a large stone was encountered it was broken up by a drilling bit, which was churned up and down until the rock was broken up. The size of some of the pieces of stone brought up by these little buckets, when compared with the size of the buckets themselves, was surprising. After a casing had been sunk and tested to see that it had the bearing capacity required by the Public Service Commission, it was filled with concrete, thus completing the pile. The buckets frequently operated in 25 ft or more of water, and one of them could excavate from 3 to 8 lin. ft. of material in a day, depending upon its character and the working conditions.

It is apparent that these little buckets are adapted for other classes of work which often cause trouble, such as digging and cleaning wells and handling materials heated in kettles or caldrons. For example, articles thrown into a hot bath could be removed in this way by perforating the blades of the bucket to allow the liquid to drain out.

Fig. 49. Counterweight Drum.

Counterweight Drum. Where a double drum engine is used in connection with a bucket, and the boom of the operating machine is to be raised and lowered, a counterweight drum will take the place of an additional drum on the engine at considerably less cost. These drums may also be used in connection with

a single drum engine when operating the various types of orange peel and clam shell buckets.

The drum is in no way connected to the hoisting engine and may be placed in any convenient location for the leading of the holding line to the bucket and the counterweight line to the counterweight.

In operation, the bucket, being lowered, raises the counterweight; when being hoisted the counterweight rotates the drum, taking up the slack in the closing line, and when the dumping point is reached the band brake holds the bucket at any desired point. The band brake may be operated by a foot or hand brake.

A drum, similar to the one shown in Fig. 49, weighs approximately 1,100 lb. for shipment and costs $235 f. o. b. New York.

Gasoline excavator for operating a clam shell or orange peel bucket has a 30-ft. boom and is equipped with a two-drum control to operate any standard bucket. The manufacturer claims that with a ¾-yd. bucket in sand, stone or gravel the daily average is 10 to 15 cars per day. This machine has the following general uses: digging sewers, cutting gravel banks, removing overburden, dredging, excavating and rehandling material. The average working speed is estimated to be from 1 to 3 buckets per min., with a capacity in ten hours of from 400 to 600 cu. yd. depending on the material. The shipping weight is approximately 32,500 lb. and the price is $9,500.00, bucket extra.

LAND DREDGE OR GRAB BUCKET EXCAVATOR

In building irrigation ditches in the Modisto and Turlock districts along the San Joaquin river in California in sand and hardpan a land dredge or grab bucket excavator was used for part of the work. The machinery is mounted on a skid platform 18 x 30 feet which rests on movable wooden rollers running on planks on the ground. The dredge moves along the axial line of the canal receding from the breast as it is excavated. It is moved ahead from 3 to 5 feet at a time by means of a steel cable anchored to a "dead man" and wound on a drum driven by the engine. The A-frame which supports the boom is 20 feet high. This boom inclines about 45° and may be swung 180° horizontally by a bull-wheel but has no vertical motion. The bucket is of the clam shell type, one cubic yard capacity, weighing 2,800 lb. The operator stands on a platform on the A-frame and controls the machine by 3 levers and 2 foot brakes. A 25 hp. single cylinder gasoline engine furnishes the power and drives a series of combination gear and friction brake drums controlling the motion of the excavating bucket. The machine

cost $5,000. Wages of the crew of 5 men and a team during one month amounted to $305.00. The supplies, which included 400 feet of ⅜-in. hoisting cable costing $50.40, rollers costing $21.00, a large intermediate gear costing $14.00, depreciation of machine $40.00, and gasoline, oil, explosives, etc., amounting to $216.24. Fourteen thousand cubic yards were excavated at a cost of $0.035 per cubic yard.

Fig. 50. Clam Shell Dredge Cleaning Canals in Imperial Valley.

Traction driven machines (Fig. 50), equipped with 15 cu. ft. clam shell buckets, were used by the California Development Co. for cleaning canals too small to float dredges. These machines have a 40-ft. steel boom carried on an all steel frame. The maximum width of cut is 14 ft. The power is supplied by a 15-hp. gasoline engine The machine has two forward traction speeds and one reverse. These machines cost $5,000 each (about 1910) and the cost of handling material with them was about 13 cents per cu. yd.

SECTION 16

BUILDINGS

The only buildings that properly need be described in a book of this character are those of a temporary or semi-permanent character.

Contractors' Portable Iron Buildings. The following notes appeared in the *Engineering Record,* Oct. 26, 1912.

Several portable iron buildings were erected to provide quarters for the construction force, and to house materials and supplies used in building a power plant for the Northern Ohio Traction & Light Co. near Akron, Ohio. The smallest building is a powder house, 12 x 12 ft. in plan. An office 12 x 32 ft., shown in the

Fig. 51. Sectional Metal Building for Construction Work.

accompanying illustration, a bunk house, 12 x 28 ft., and a storage house, 12 x 28 ft., also were provided The buildings are constructed in units so the width or length may be increased by any multiple of 4 ft. Sills of 8 x 10-in. timbers, pinned together at the corners, were provided. With these in place for each building, the front corners of the latter were bolted down and

then the balance of the sections were erected in successive order. Each section is fastened to the next by means of three bolts. As fast as the sides were in place the roof could be erected without any framing, as the buildings are complete in themselves.

Dry House. Mr. R. E. Tremoureux in the *Mining and Scientific Press*, June 17, 1916, has written the following:

A new dry-house was built at the Champion mine, Nevada City, California, in November, 1915, to accommodate 320 men, at an approximate cost of $8 per man. The house is built on a level waste-dump, with concrete walls four inches above the floor-level. The floor contains 2,160 square feet of concrete put in at the following cost per square foot:

Labor	$0.044
Supplies	0.069
Total	$0.113

The floor is built with a grade to the centre of the shower-baths. The building is 36 by 60 ft. and 12 ft. high, with a 9-ft. rise in the roof. The building contains 5,254 board-feet of lumber, built at the following cost per M board-feet:

Labor	$14.80
Supplies	21.20
Total	$36.00

The roof and sides, having 5,407 square feet of outside surface, including doors and windows, cost per square foot:

Labor	$0.008
Supplies	0.143
Total	$0.151

The house is built to contain 8 sections of suspended lockers, each locker containing 40 compartments. The lockers are counter-balanced on the outside of the building and can be raised and lowered easily by one man. When raised the bottom of the locker is eight feet from the floor. There are four showers in the main room and one in the foreman's office. The wash-stands are built along the sides of the showers. The dry is heated through 2-in. pipe-radiators, by an Ideal hot-water boiler. The total summarized costs are as follows:

	Labor	Materials and supplies	Total
Grading	$ 19.50	.....	$ 19.50
Concrete walls	19.13	25.50	44.63
Concrete floors	93.75	149.55	243.30
Building	77.75	111.39	189.14

	Labor	Materials and supplies	Total
Roof and sides	41.50	779.08	820.58
Windows and doors	29.00	1.06	30.06
Lockers	217.50	237.84	455.34
Ideal boiler erection	12.63	200.30	212.93
Boiler radiators	103.75	120.55	224.30
Hot-water boiler	13.37	20.80	34.17
Electrical work	20.98	10.00	30.98
Showers	25.38	41.22	66.60
Foreman's office	11.75	7.50	19.25
Pipe work	20.62	36.65	57.27
White-washing	24.50	3.20	27.70
Sundry	38.75	2.63	41.38
Superintendence	60.00	.....	60.00
Totals	$829.86	$1,747.27	$2,577.13

Car Camps. The following was taken from *Engineering News Record*, Feb. 27, 1919. Car camps on wheels with a bunkhouse and mess-hall unit in each outfit repay their cost each season on road maintenance in Gogebic County, Michigan, by reducing lost time of men and wear and tear of camp equipment. An outfit, with a mess-hall unit complete, as illustrated, and an

Fig. 52. Portable Car Camp.

exactly similar bunkhouse unit without furnishings, was built by a local wagon maker for $675.

The wagons are standard-gear, with ⅝ x 4-in. tires, 3¾ x 12-in. skeins, 28-in. front wheels and 36-in. rear wheels. The bolsters are made as wide as possible; in this case they are 40 in., and the front bolster is so arranged that the front wheels can turn under the body as far as the reach.

The bunkhouse unit will accommodate cots for 12 men. A 7,000-lb. tractor hauls each unit easily.

The City of San Francisco has adopted a standard design for bunkhouses on the Hetch Hetchy project. This is not only to simplify material billing and construction, but in order to fit in with the necessity for moving camp frequently. Because

practically all parts of the work are reached by the city's 68-mile railroad, it is desirable to use bunkhouses that can be readily loaded on a flat car.

Two standard sizes are in use, a 10-ft. x 16-ft. house for eight men and a 10-ft. x 30-ft. house for sixteen men. Both use two tiers of bunks. The design calls for 2-in. x 4-in. studding, 4-in. x 4-in. corner posts and battons over the joints between the 1-in. sheathing. There is nothing unusual about the design except, perhaps, that the 4-in x 6-in. floor plates are always used in full length pieces to afford a substantial "bottom" on which the house can be jacked up and skidded. The frame is well braced to withstand the racking incidental to moving, and a tar-paper roofing keeps the weight to a minimum. The lumber in the larger size structure totals only about 3,000 ft. b m. Where a camp is to be maintained for a short time only, the custom is to skid the bunkhouse from flat car onto a crib built up alongside to suitable height and leave it there until the next move is in order.

Portable Sectional Bunkhouses. The following is taken from *Engineering News Record*, Jan. 17, 1918. The standard design adopted by the Pennsylvania R. R. for wooden buildings of this sort is shown in Fig. 53.

The buildings are of light framing, with sheathing of tongued-and-grooved white pine, and roof panels of plank covered with tar paper They are built in 10½-ft. lengths, and have a uniform width of 20 ft. and height of 16 ft. from floor to ridge. The exterior is covered with pebble-dash roofing paper. For semi-permanent structures, as at railway shops, the floors are set on concrete piers about 18 in. above the ground, and roof gutters and downspouts are provided.

The buildings can be made of any desired length, and equipped for various uses. The bunkhouse has usually five sections. It has steel double-deck bunks, and is fitted with lockers and stationary washstands supplied with running hot and cold water. Shower baths are provided whenever possible. A 73½-ft. mess-room has two sections (21 ft.) for the kitchen, and five sections (52½ ft) for the dining room. This latter has six rows of benches and two tables. The commissary building for the store-keeper or timekeeper has two sections.

Sides, ends, floor and roof form separate sections or panels. These are packed flat for shipment, and material for four buildings can be transported easily on a flat or gondola car. When erected, the sections are put together with hooks and eye-screws. The separate panels are readily treated with disinfectants, applied by brush or spray, and this work is easier and

more effective than disinfecting a car. Cost of construction is about 7½ cents per cu. ft. Unloading and erecting costs about $5 per unit, dismantling and loading the same.

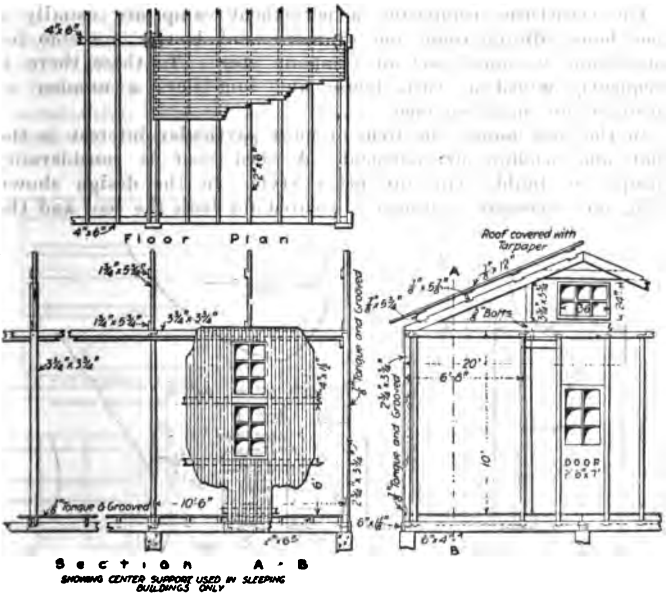


Fig. 53. P. R. R. Standard Portable Bunk House.

Construction Camp for the Town of Torrance, Cal. Mr. Ralph Bennett in *Engineering News*, Aug. 27, 1914, has written the following:

A camp, whether temporary or permanent, should be located on gently sloping ground which will provide satisfactory drainage.

The most important requisite is water. Provision should be made for securing a supply which will be ample and uncontaminated during the entire duration of the work. Water should come to the camp under sufficient pressure for ordinary tank use and should be supplied through pipes 3 or 4 in. in diameter so that one or two fair-sized fire streams can be used. There should be a 2-in. hose outlet with 100 ft. of 1½-in. cotton factory fire hose located to cover every building.

As a matter of fire protection, as well as of convenience, all buildings should be wired for electric lights, and the use of lanterns should be restricted to those classes of work which require portable outdoor lights.

The structures composing a permanent camp are usually a cook house, dining room, one or more bunk houses, a stable for horses and a commissary or company store. To these there is frequently added a wash house and sometimes a number of cottages for married men.

In the cook house, the item of most particular interest is the roof and window arrangement. A shed roof is considerably cheaper to build than any other style. In the design shown (Fig. 55), necessary stiffness is secured for both the roof and the

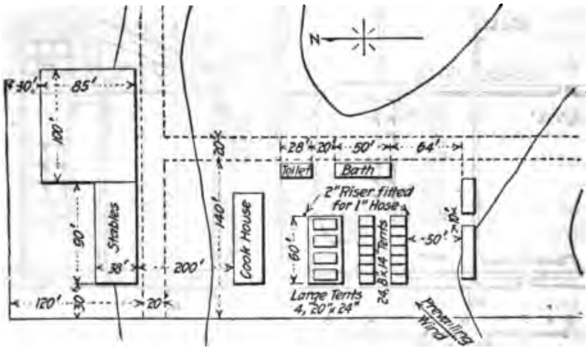


Fig. 54. General Layout of Construction Camp for Town of Torrance, Cal.

building by the use of a simple nailed truss under every rafter. The window openings are practically continuous, are screened on the outside and have the sash mounted against the inside of the boarding without frames. These sashes can be leaned back during the summer or pulled up to close the openings, as the climate warrants. This side of the cook house should preferably face the east or northeast in order to obtain the early morning sunlight without becoming overheated during the afternoon. The high windows furnish an even light on all tables and produce satisfactory ventilation with but little draft. In a cook house larger than the one shown there should be a door opposite each runway. All doors must be of ample size and arranged to swing out. All openings must be screened.

The main stove should be of ample size and should be set on a concrete or brick or rock base large enough to be safe from accidental ignition.

The stove should have a water-back with large storage-tank.

The larger the sink and drainboard the less trouble there is in retaining flunkeys. The tables should be covered with white oilcloth. White enamel ware appears to give better service than any other style of table furnishing. Benches and tables should be substantial. The tables should be 4 ft. wide. This class of furniture is thoroughly satisfactory for camp use.

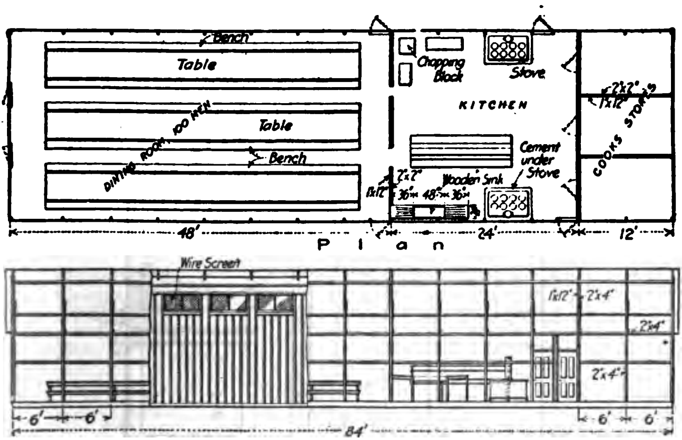


Fig. 55. Cook House and Dining Room, Torrance Construction Camp.

If, as is now frequently the case, the management provides an occasional lecture or moving-picture show, this high-ceiling room is quite satisfactory.

The bunk house (Fig. 56) is in its general arrangement typical of a large number of bunk houses in use in California. The use of a shed roof with high windows furnishes better light and air than does the old style peak roof. In this particular house the bunks are usually commodious and are provided with a continuous seat alongside of each lower bunk in preference to a single central bench. Steel bunks are sometimes substituted for wooden frames. They have the advantage of being vermin-proof, but the disadvantage of leaking loose straw and other

material more or less continuously. Except in very severe climates, no stove should be permitted in a bunk house. If there is a very considerble number of employees, the construction of a number of medium-sized bunk houses is much to be preferred to the use of a single large building. The loss in case of fire is less and the men are better satisfied in that they can separate by nationalities and trades.

Certain classes of employees, such as cooks, stable men, foremen and superintendents, require separate houses in any case.

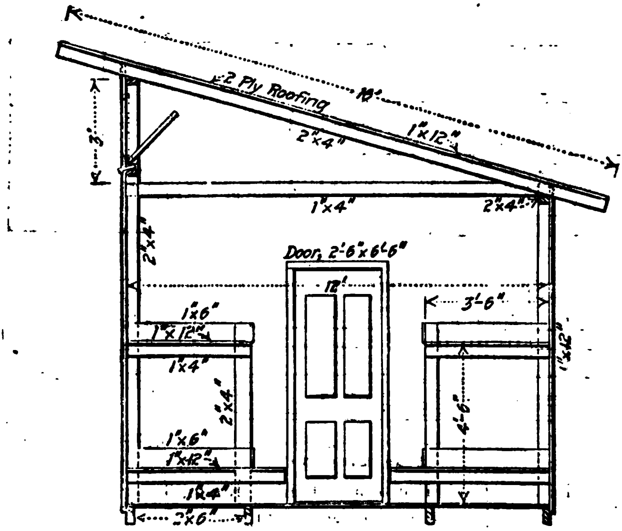


Fig. 56. Cross-Section of Bunk House.

Shed-roof buildings of the same type can be used but subdivided crosswise into the necessary number of apartments.

A combined loafing room, bath and wash room should be constructed in a camp housing less than 100 men. In larger camps these can be separated to advantage. The stove here should have a water-back to supply water for the shower baths and for washing the men's clothing. There should be with it a tank of very considerable size. If the employer furnishes small wash tubs in place of the traditional 5-gal. oil cans, the men will appreciate them. For washing the face and hands, there should

be a row of faucets located out of doors in the sun above a wooden trough equipped with graniteware wash basins.

The sanitation of the camp and minor policing should be in charge of a sweeper or sweepers who would clean up daily, supply necessary wood and start the wash-house fire before the end of the day. He should keep all buildings locked during the day and when unoccupied.

Ample supplies of disinfectant should be allowed and there should be a periodical whitewashing of the entire property.

Night shift employees should be, so far as is possible, segregated into a separate bunk house.

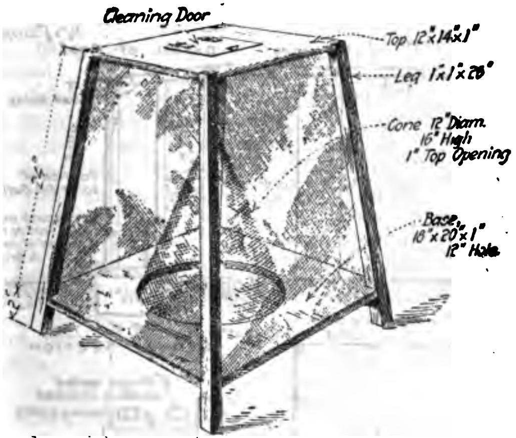


Fig. 57. Fly Trap for Construction Camp.

Water closets equipped with first-class plumbing should be installed in any camp where the duration of the work will warrant it. They are more sanitary and agreeable in every way than the best possible sinks, and have the very great advantage that they can be so screened as to minimize the possibility of fly-transmited infection.

The most serious foe of health in the camp is the fly. Flies live on garbage and breed in manure. Manure should be hauled away daily and garbage should be kept covered. A number of fly-traps similar to the one shown by Fig. 57 should be located around the camp and emptied very frequently. The trapped flies can be stunned by dashing distillate or gasoline into the cage and can then be shaken out and burned.

A camp of any size employs a large number of horses and they, with their feed and equipment, occupy a stable of considerable magnitude. The preferred arrangement of camp stables places the mangers lengthwise of the center line with the feed on one side and the animals on the other. Centerpost construction will be more economical here than a single-span shed roof. If the stalls are on the south side of the building and are somewhat sheltered from the prevailing wind, that side of the stable can

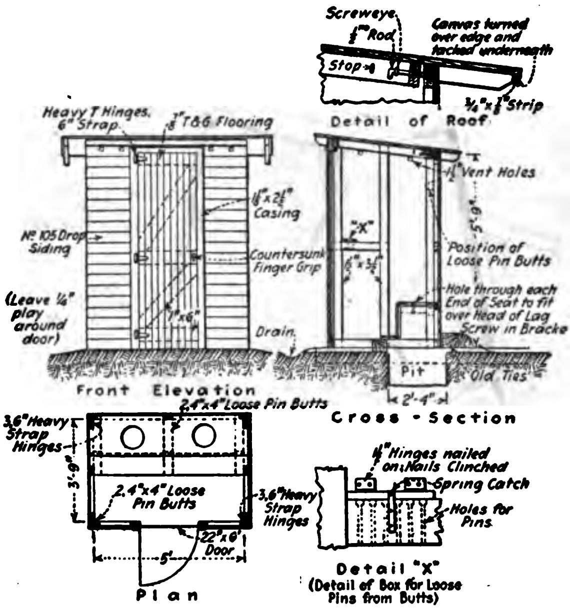


Fig. 58. Portable Dry Closet for Camps.

be left almost entirely open. The depth back of the animals should be ample for a convenient runway. The harness of work animals is nearly always hung on a bracket opposite the animal, but there should be a locked harness room for storing and repairing spare equipment. The bigger the corral and the bigger use there is made of it, the less trouble there is in maintaining the health of the animals. A great many horse diseases are communicated by dirty water in drinking troughs. Series troughs should not be used on account of this possibility. Small, short,

individually-filled troughs, emptied and cleaned once a day, are much to be preferred.

Folding Portable Dry Closet. The following appeared in *Engineering News Record*, July 17, 1919.

A standard design of dry closet, with folding portable building, designed for temporary use by bridge gangs, etc., on the Nashville, Chattanooga & St. Louis R. R., and adapted also for use at construction camps, is shown in the accompanying cut. One end is hinged to the back and the other to the front, so that the building can be folded up for transportation. Three heavy 6-in. trap hinges are used at each of these corners. The other two corners are each fitted with two 4 x 4-in. loose pin butts for holding the building together when it has been assembled, a box being provided for holding the pins when the building is dismantled.

The drip board is provided with two pieces of No. 27 galvanized iron, 12 x 19 in., centered on holes at the front of the seat. The foot board, drip board and seat are connected by 5-in. strap hinges so that these three parts can be folded together.

For the roof, the plank sheathing receives a coat of white lead and linseed oil, and while this is wet it is covered with heavy roofing canvas secured by flat-head copper tacks. Two coats of white lead and oil are then applied. Screws and cement-coated nails are used in the building, which gets two coats of paint inside and outside.

Standard portable metal garages cost as follows f. o. b. Milwaukee, Wis.

Size	Approximate weight in lb.	Price
	26 gauge single wall	
10 by 14	1020	$188
10 by 18	1310	235
12 by 18	1575	277
18 by 20	2623	429
20 by 20	2914	486
	26 gauge double wall	
10 by 16	1743	$272
10 by 18	1965	308
12 by 18	2362	361
18 by 20	3934	543
20 by 20	4371	616
	20 gauge single wall	
10 by 14	1785	$230
10 by 16	2083	261
12 by 16	2442	330
18 by 18	4130	475
20 by 20	5109	606

For swinging door add $8.00 each, for swinging windows add $5.50 each.

SECTION 17

CABLEWAYS

The following notes on cableways are from Chapter XIII of Gillette's "Earthwork and Its Cost."

Cableways properly include only those means of haulage wherein the load is suspended beneath a cable by means of a carriage whose grooved wheels run on top of the cable.

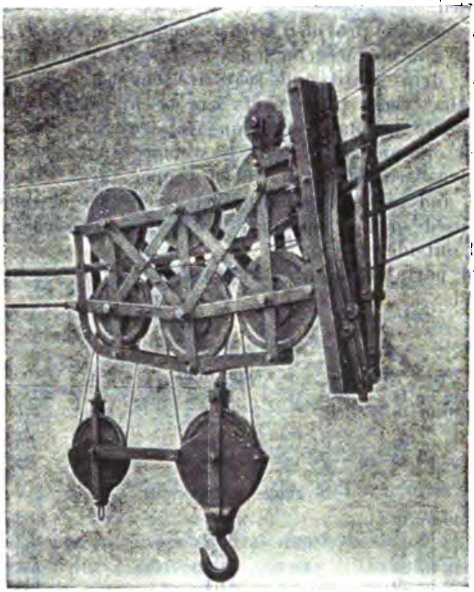


Fig. 59. Standard Cableway Carriage.

Cableway. The term cableway was coined in order to indicate an aerial transportation machine in which the single load was hoisted as well as transported on a single strand of cable. The term "aerial tramway" applies to a machine in which the

loads, often small and numerous, are hauled along a fixed track by a moving traction rope. On the aerial tramway the carrier may be arranged to pass the towers or other supports, and this is one of the distinctive points of difference between an aerial tramway and a cableway. In the aerial tramway the cables are tightened by means of weights or similar tension device, but in the case of the coasting or gravity cableway no tension devices are required.

A cableway consists essentially of a main cable suspended between two towers or anchorages, serving as the track for a trolley carrying the load. This load is pulled back and forth by smaller cables. Where the track cable is so arranged that the slack may be increased or diminished at the will of the operator, thereby directly raising or lowering the load, the machine is termed a "slack cableway." Similarly, when one end of the cableway can be raised or lowered so that the load may slide through gravity to the other end, the machine is termed a "coasting" or "gravity cableway." When the loads on a cable way are all to be carried in one direction it will often pay to have the dump end of the cableway at a lower point than the loading end.

Another type of cableway is that in which the track cable is also the hauling and return cable, the cable being continuous from one end of the span to the other and back again. The bucket is either firmly fastened to the cable or held in place on it by friction.

The Economic Use of cableways is limited by the following conditions: (1) A sufficient quantity of work to pay the cost of the first installation, plus the cost of ensuing removals and re-installations, and (2) a sufficient quantity of work within the length of span and within economical reaching distance each side of the cableway to repay the cost of one installation and removal. These conditions are often fulfilled on trench and canal excavation and in the construction of dam foundations.

Cableway Costs. The cost of a cableway depends upon the length of span, height and type of towers, and the quantity and kind of power required. In general, a cableway, designed to operate in earth excavation or for conveying buckets, costs from \$8 to \$15 per ft. of span, for spans of 400 to 800 ft., and from \$6 to \$12 per ft. of span, for spans of 1,000 to 2,000 ft.

A Duplex Cableway (two complete cables, 15 to 20 ft. apart, on common towers) will cost about \$11.50 per ft. of span, for spans of 2,000 ft., when the towers are from 75 to 130 ft. high.

Cableway Systems. F. T. Rubidge, in *Engineering and Contracting*, Jan. 8, 1908, gives the following: Mr. Rubidge defines

an inclined cableway as one having sufficient inclination so that the power required to hoist the load is less than that required for conveying. This enables the use of a single rope for both hoisting and conveying. Where the inclination of the cableway is less than this, it is classed as horizontal, though the ends of the span may be at different levels.

Horizontal Cableways. In this system, in addition to the cable and carriage that travels upon it, there must be provided independent means for hoisting and conveying the load.

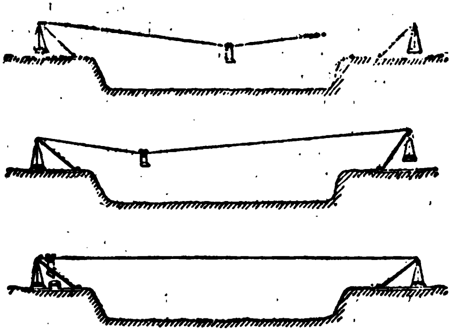


Fig. 60. Balanced Cable Crane Horizontal Cableway.

In the case where the motor is installed upon the carriage, the latter is propelled by gearing to the sheaves traveling upon the main cable. As a cable with both ends fixed takes the approximate form of an ellipse, it would be impossible for the carriage to climb the steep part of the curve at either end. To overcome this, the bents or towers are free to move at the top in the direction of the cable and they are so weighted that the main cable is under constant tension. This causes the carriage to travel an approximately uniform grade. This device is called the Balanced Cable Crane. The fact that the cable must sustain the additional weight of the motor and motorman is a disadvantage, but in many cases it is offset by the advantage of having the operator close to the points of loading and dumping.

Arrangement of Hoisting and Conveying Ropes. In cases where the engine or motor is located at the end of the span, ropes in addition to the main cable are necessary, the one for hoisting, the other for conveying. When an orange-peel or other self-filling bucket is used, a third rope and an extra drum on the engine must be provided.

Figs. 61, 62 and 63 show three different arrangements of hoisting and conveying ropes which have been adopted by the Lidgerwood Mfg. Co., the Lambert Hoisting Engine Co., and the Trenton Iron Co., respectively.

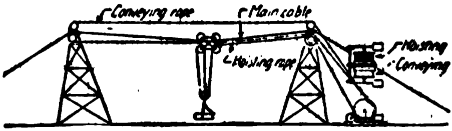


Fig. 61. Arrangement of Lidgerwood Cableway.

In the arrangement adopted by the Lidgerwood Co. the load is first hoisted to the desired height. During conveying, both hoisting and conveying drums must be in operation, and of the same diameter so that the load may remain at a constant distance from the cable.

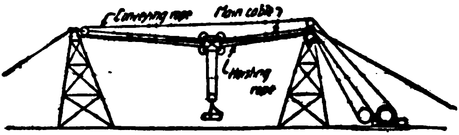


Fig. 62. Arrangement of Lambert Cableway.

In the arrangement used by the Lambert Co., the engine drums have different diameters, the larger being the conveying drum. This permits simultaneous hoisting and conveying, and a conveying speed greater than the hoisting speed.

The arrangement used by the Trenton Iron Co. was devised to obviate the necessity of using carriers to prevent sagging of

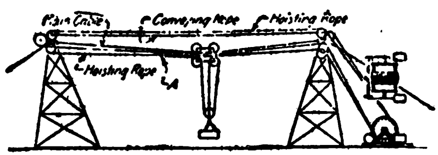


Fig. 63. Arrangement of Trenton Iron Co.'s Cableway.

the hoisting rope. The hoisting rope is attached to an endless rope at the point A by means of a specially constructed swivel connection. The endless rope is passed a number of times around an elliptic-faced drum, to give sufficient friction for hoisting the

load. In operation both hoisting and conveying drums are in motion during conveying, and both must be of the same diameter.

Fall-Rope Carriers. The economical operation of a cableway depends in no small measure upon the carriers employed. Their function is to prevent excessive tension (due to sag) in the hoisting rope, so that when the load is detached from the fall-block, the latter, while free, will not ascend to the carriage. Even with the use of carriers it is necessaary to use a weighted fall-block, so that it may be raised or lowered by the engineman when no load is attached.

The following are styles of carriers in use:

(1) *Chain-Connected Carriers.* These consist of a supporting sheave which travels upon the main cable, below which, in the same frame, are sheaves for the support of other necessary ropes. The side plates which form the frame for the sheaves must project beyond them, so that when adjacent carriers strike each other the sheaves will not come into contact. The connected

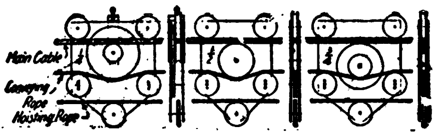


Fig. 64. Lambert-Delaney Carrier.

carriers are attached at one end to the lower and at the other to the carriage. When the carriage is close to the head tower (engine end), the carriers are all in contact with the chains hanging in loops below. As the carriage moves toward the tail tower the carriers are spaced along the cable with the chains hanging in festoons below.

(2) *Button-Rope Carriers.* With this carrier an additional rope across the span is required. It is fixed at one end and kept at a constant tension by a weight at the other. At intervals along the rope are affixed "buttons" with a gradation of diameters, the smallest being the first from the head tower. The carriers are provided with eyes having a corresponding gradation of diameters, slightly smaller than the buttons, through which the button rope is threaded. The carriage is provided with a projecting arm or "horn," which picks up the carriers as each is met during the travel of carriage toward the head tower. All the carriers are riding upon the arm when the head tower is reached. On moving away from the head tower, the first button passes through the eyes of all the carriers but the last. This

one is snatched from the arm and deposited upon the cable. The second button selects the next carrier, and so on.

(3) *The Lambert-Delaney Carrier.* This is rather an ingenious device, depending upon the fact that points along the vertical diameter of a horizontally rolling wheel travel at different velocities. The rolling wheel in the case of the carrier is inverted, and rolls upon the under side of the main cable. The conveying rope is the rolling force, and is applied at different distances from the center of the rolling sheave to obtain the required variation in velocity of travel. Fig. 64 illustrates the construction. It will be noticed that, in the quarter speed carrier, a yoke with set screw is used to increase the friction between the rolling sheave and cable.

The advantages and disadvantages of the above types of carriers are as follows:

Chain-connected Carriers. Advantages: (a) Simplicity. (b) Not easily deranged. (c) Positive spacing. Disadvantages: (a) Extremely heavy. (b) Considerable wear. (c) Power required to stretch chains as carriage nears tail tower.

Button-rope Carriers. Advantages: (a) Extremely light. (b) Minimum wear to both carrier and cable. (c) Positive spacing. Disadvantages: (a) Maintenance of button rope.

Lambert-Delaney Carriers. Advantages: (a) Neither rope nor chains required for spacing. (b) Weight of carriers uniformly distributed at all times between carriage and towers. (c) Moderate weight. Disadvantages: (a) Double bending of conveying rope while passing through carriers, causing short life of rope. (b) Variable spacing due to slip between rolling sheaves and cable. (c) Large number of sheaves to maintain.

The arrangement shown in Fig. 63 is "the Laurent-Cherry" system, which employs no carriers, as above mentioned. The advantages are: (a) A minimum of working parts not easily accessible. (b) A minimum of dead weight to be sustained by cable. The disadvantages are: (a) The endless hoisting rope is subject to considerable wear owing to constant slipping on elliptic-faced drum. (b) When hoisting from a considerable depth below the main cable and conveying toward the tail tower, there is a limit to the distance of approach to the tail tower, owing to the fact that connection at A, Fig. 63, cannot pass over the tail tower sheave. On this account a greater span is necessary under such conditions than in the other arrangements.

The Incline Cableway. It is obvious that when the inclination of the cable is such that greater power is required for conveying than for hoisting, the carriage will remain stationary on the cable while the load is being hoisted, even though no conveying

or endless rope is used. Should the load be hoisted until the fall-block comes into contact with the carriage, the further pull on the hoisting rope will cause the carriage with the load to move along the cable. A single drum engine is, therefore, all that is necessary.

The simplest form of incline cableway is used where the loading and unloading are always done at the same point. In this case a stopping block is clamped to the main cable to prevent the carriage running below the point of loading, and a self-engaging latch is clamped to the cable at the unloading point to hold the carriage in position while the load is lowered.

Where it is necessary to provide means for loading and unloading at any point, an endless rope is used as in the horizontal cableway, but no power is necessary for its operation, its function being merely to hold the carriage at any desired point. This is accomplished by passing the endless rope a number of times around an elliptic-faced drum provided with brake only.

The Aerial Dump. The range of the cableway is largely increased by the possibility of dumping the contents of the skip at any point in its travel by the manipulation of a lever at the engine. The skip employed has an open end, so that tilting is all that is necessary for dumping. The skip is suspended from the hook of the fall-block by chains with hook ends attached to the sides and ends of the skip. The end of the skip is also attached to another fall-block reeved with the dump line. The latter necessitates two additional sheaves below the cable in the carriage, and is reeved in a manner similar to the hoisting rope. In the Lidgerwood self-dumping device the dump line is wound on the hoisting drum, and when it is desired to dump the skip, the line is shifted by a suitable mechanism upon an increased diameter of drum. This causes the dump line to be drawn in at a higher rate of speed than the hoisting rope, and results in the tilting of the skip for discharging the contents.

In the Lambert system the dump line is attached to its own drum mounted on a shaft with the hoisting drum, in close contact with the latter and so arranged that the hoisting drum, when released with a load, can make only a half revolution while the dump line drum is stationary. During hoisting, the hoisting drum drives the dump line drum and, both being of the same diameter, the skip remains horizontal. When it is desired to dump the skip, the brake is applied to the dump line drum and released on the hoisting drum.

Lubrication. The fact that the sheaves in the carriers, carriage, and tops of towers are not easily accessible renders self-

lubricating bushings desirable, and they are generally used. Their use, however, does not mean that little attention is required. The carriage and hoisting rope especially should be carefully examined daily, for, while the apparatus is seldom used to transport men, the load is generally conveyed above them.

Towers. Either tower may be fixed or movable. When both are movable the tracks must be parallel. The parallel track arrangement was used extensively in the excavating of the Chicago drainage canal. A common arrangement is the radial cableway, where one tower is fixed and the other movable.

Movable towers are usually mounted on standard railroad wheels. The track consists of six or seven lines of rails, and rail-braces should be used plentifully. Power for moving the tower may be obtained from the winch-head on the cableway engine, or, if the tower must be moved often, a special engine is provided. Movement is accomplished by block and tackle between the engine and anchorage at either end of the track. Considerable power is necessary on account of the large amount of friction between flanges of wheels and rails.

For low towers in fixed positions the "A" frame is commonly used, but the head tower should not be so low, or the engine so close to it, that the fleet angle of the ropes becomes excessive. In some cases, especially in incline cableways, the tail tower may be dispensed with and a rock anchorage substituted. High towers are common where height is desired for disposal of material beneath the cable, and in very low spans where the deflection of the cable is necessarily large. They are usually constructed of wood, for the reason that the cost is less and in most cases they will last as long as the cableway is required. The base of the tower is usually from one-third to one-half the height. Steel masts are sometimes used for tail towers. They require at least three strong and well anchored guy lines. The base has a ball and socket joint of steel castings, and the customary wood saddle is bolted to the top for the main cable.

Main Cable. The essential features of the main cable are strength, lightness, flexibility, and a surface which will not only receive the least wear but impart the least wear to the sheaves rolling upon it. The standard hoisting rope is objectionable from the standpoint last mentioned. Though less flexible than the hoisting rope, the locked-wire rope is generally used for the reason that the other qualities are possessed to a much greater degree.

Fig. 65 shows the socket used on the locked-wire rope. There are six wedge segments in each cone, with the exception of the smallest, which contains four.

Means are provided for taking up the main cable when the

deflection has become excessive, due to stretching. In short spans a turnbuckle is inserted in the sling which passes around the anchorage and thence through a sheave attached to the end of the cable. For long spans, special double or triple sheave blocks are used, reeved with wire rope. The take-up is usually located at the head tower end so that the engine may be utilized when taking up is necessary.

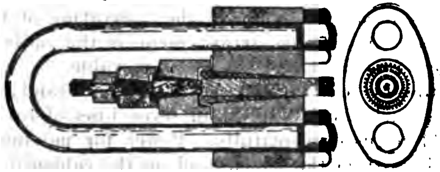


Fig. 65. Step Socket for Main Cable.

Anchorages. The tension of the main cable is usually from five to six times the load, depending upon the deflection. Anchorages secure beyond all possible doubt, are essential, as their failure would prove disastrous to the cableway and imperil the lives of men. Since it is impossible to calculate the resistance offered

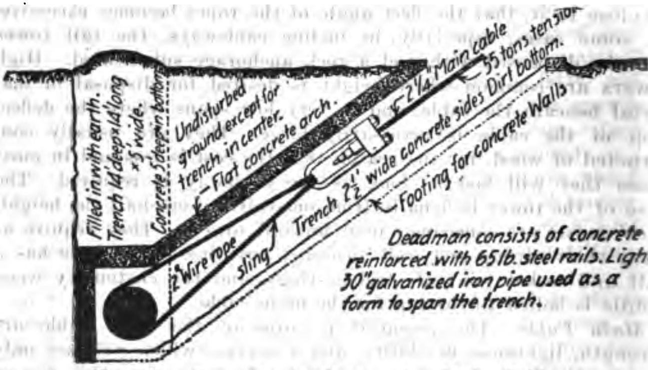


Fig. 66. Concrete Anchorage for Main Cable.

by the earth to a buried anchorage, it is usual to find a much stronger anchorage than is necessary. The usual form for moderate tensions — say up to 30 tons — is a well tarred oak log about 18 in. in diameter and 16 ft. long, buried to a depth of 8 or 10 ft. If longer life is desired, or if the tension is greater, a concrete anchorage may be substituted. A form which has been successfully used is shown in Fig. 66.

A Coasting Cableway. This is a simple device of the nature of a cableway in which a line, starting at a point about on a level with the base of a pile driver or derrick is run over a sheave on the top of the leads or mast and down to the engine drum. A snatch block travels on this cable. A tag rope is fastened to this block and may be controlled by snubbing around

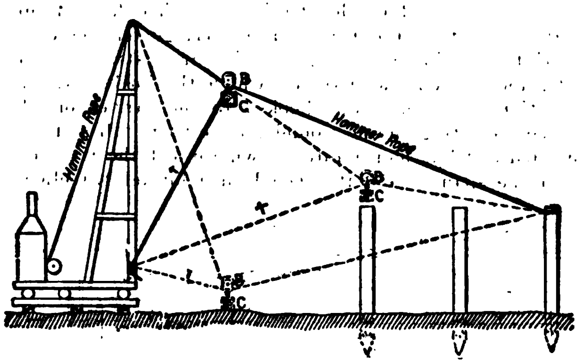


Fig. 67. Coasting Conveyor.

a post or a winch or drum on the engine. Heavy loads can be moved easily by raising or lowering one or both of the lines, as illustrated in Fig. 67.

The author has used this device on a small job for handling heavy timbers and pile caps. A floating derrick was utilized for the same purpose in the construction of the pile foundation for a

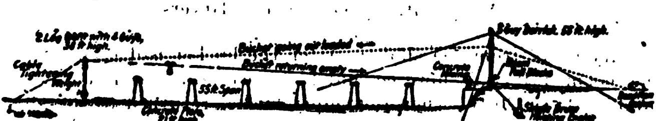


Fig. 68. A Cableway for Conveying Materials in Building Concrete Piers, at Northumberland, N. Y.

large sewer in New York (see *Trans. Am. Soc. C. E.*, Vol. 31, p. 673). It may be adapted for moving earth.

Parker and Flynn used an inexpensive cableway for constructing concrete piers at Northumberland, New York. This device was illustrated by them in *Engineering News*, June 26, 1902. It consisted of a 55-ft. guy derrick, without boom, placed near the edge of the bank at the side of the river, and a two-legged bent

placed in the middle of the river. The cable was of ¾-in. steel and was stretched from a dead man on the shore about 150 ft. back of the derrick, past and just crossing the derrick to the bent. Under the top of the bent at the end of this cable hung two weights which consisted of scale pans loaded with concrete. In passing over the bent the cableway was carried on a 16-in. block. The boom fall of the derrick was then hooked onto the cable at the foot of the mast. The carriage on the cable consisted of two 16-in. cable-sheaves with iron straps, forming a triangle, and carrying a chain on which the bucket was hooked. In operation the bucket was hooked to the carrier on shore, a single drum hoisting engine wound up the boom fall and the cable was hoisted until it had a pitch down toward the river of 18 or 20 ft. in the span of 450 ft. The loaded bucket travelled under

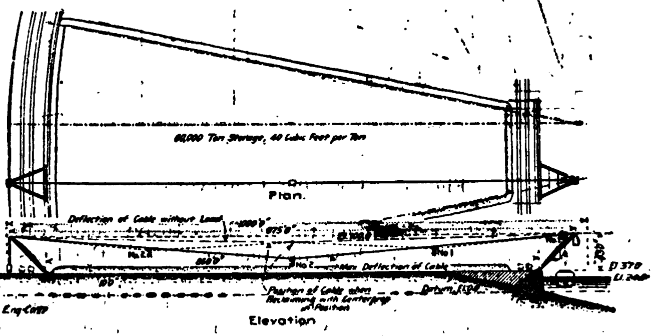


Fig. 69. Cableway in Which Sag in Cable is Practically Done Away with by Oscillating Towers.

gravity away from the shore. After the bucket had been dumped the boom fall was lowered until the cableway had a reversed pitch of 18 or 20 ft., when the empty bucket returned to the shore.

The speed of the bucket was governed by the slope of the cable. When the cable was at its extreme grade the bucket would run from the platform to the bent a distance of 450 ft. in 35 seconds and return in about the same time. This device might be employed for earth excavation.

A Balanced Cable Crane. *Engineering and Contracting*, Nov. 13, 1907, gives the following: This cableway was installed at a coal storage plant at Watertown, N. Y. It is equipped with electric motors not only on the trolley or carriage, but also on each of the oscillating towers. In this manner each tower can be propelled along the single rail track. It is not necessary that

the two towers move simultaneously. Indeed, one tower can travel 25 ft. without moving the other tower. The towers have a traveling speed of 43 ft. per min., when it is desired to shift them.

The electric load carriage, or trolley, handles a 3-cu. yd. clamshell bucket, and has a traveling speed of 1,500 ft. per min. and a hoisting speed of 80 ft. per min., with a 60-hp. motor.

It is interesting to note that this cableway as built commands about 9,000 cu. yd. of material per ft. of depth. It might easily be economical equipment to use on an excavating job.

A Combination Cableway and Derrick. *Engineering and Contracting*, Feb. 24, 1909, gives the following:

To-day the use of cableways for building sewers is rapidly increasing, as is also the use of portable derricks. With both machines good work can be done both in excavating the trench and in placing materials in the construction of the sewers. On this page we illustrate a combination cableway and derrick designed for spans up to 500 ft., that promises to find a great field of

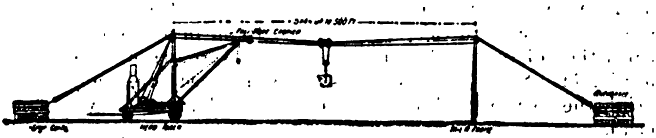


Fig. 70. Combination Cableway and Derrick.

usefulness in not only building sewers, but in many other classes of construction.

The general plan is extremely simple. The derrick is built on a car with a hoisting engine and boiler. Over the A frame for the derrick is erected a head tower for the cableway. A tail tower is erected at the other end of the work and the cableway strung and anchored to dead men as shown. In moving the cableway, only the tail tower need be taken down.

It is possible to use both the derrick and cableway at the same time, or work can be carried on with either. This arrangement means a saving in time in carrying on work. This design was gotten up by the New York Cableway & Engineering Co., 2 Rector St., New York.

Life of Main Cable. A ¾-in. wire cable used on an incline on the Chicago Main Drainage Canal lasted from 100 to 160 days, during which time it made from 30,000 to 50,000 trips, carrying from 50,000 to 80,000 cu. yd. of solid rock. Assuming the rock to weigh 4,300 lb. per cu. yd. the life of the cable was from 108,000 to 172,000 tons.

A Telpher System. *Engineering and Contracting*, Oct. 18, 1916,

describes a method of disposing of subway excavation in New York City, by telpherage.

The power for hoisting and trolleying was furnished by a 60-hp. 250-volt direct current motor. A Lidgerwood 2-drum hoist was used for hoisting and trolleying. The car was a home-made affair, composed of four standard cast iron wheels 8-in. in

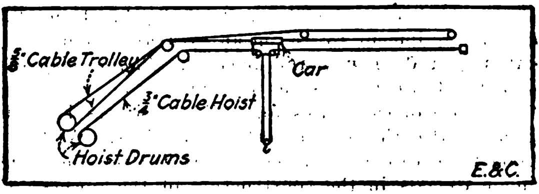


Fig. 71. Arrangement of Cables for Telpher System.

diameter, which run on two 18-in. I-beams. These wheels supported two standard cast iron sheaves, 16-in. in diameter, through which the hoisting cable ran. The cables were arranged as shown in Fig. 71. Steel buckets and skips were used for handling material, the former holding about 1 yd., the the latter 2 yd. of material.

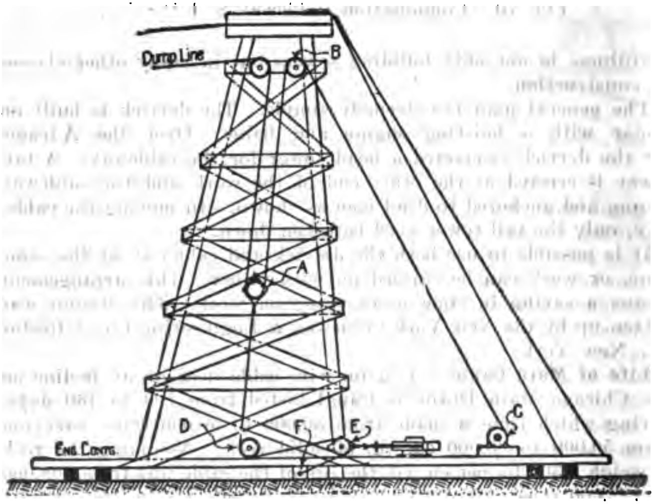


Fig. 72. Skip Dumping Device for Cableways.

A Skip Dumping Device. This was developed in connection with the Ashokan Reservoir work of the Catskill Aqueduct and is described in *Engineering and Contracting*, Nov. 9, 1910. The cableway used was of the Lidgerwood type and was equipped with Locher skip dumping mechanism.

As shown in Fig. 72 the dump line and the hoisting rope are wound on the same drum *C* in the cableway tower and all their motions coincide. The dump rope, at the tower, runs down through a fall block *A*, then up over the sheave *B*, and thence to the main drum *C*. By pulling down the fall block *A*, which is suspended in the loop of the dump line, this line is shortened, lifts the rear of the skip and thus dumps it. It is the method of pulling down this fall block which is novel. The old method was by a cable which wound upon a small drum. This method worked well, but was slow. The new method consists in pulling down the fall block by means of a cable which is fastened to the block and passes from there through a stationary sheave *D* directly below, thence through a sheave *E* fastened to the end of a piston rod, operated by a compressed air cylinder about 12 x 72 in. in size and thence back to a stationary anchorage *F* on one of the heavy timbers of the tower. By passing the cable through the sheave *E* on the end of the piston the distance through which the piston acts is only one-half the distance through which the fall block is moved. The piston is operated by compressed air which is used for operating all the machines in the work.

CABLEWAY DATA

Location	Span in ft.	Height tower in ft.	Engine cylinders—hp.	Cost	Remarks
Rochester, N. Y...	630	50	2–8¼x10 in. 30	....	2 cableways 60 ft. apart.
Sodom Dam, N. Y.	667	...	....	$ 3,800	2 in. cable
Carson cableway on trench work.....	200–300	20–35	2–7x10 in.	....	1½ in. cable; load 5,000 lb.; speed 440 ft. per min.
Chicago canal.....	550–725	73–93	2–10x12 in. 50	$14,000	Cost of cables, cars and skips, etc., complete.
Concrete work....	800	45	....	$ 4,750	For handling 1 yd. bucket.
Average cableway.	800	...	2–12x12	$ 6,500	For 5 ton load, not including towers. Electric motors, etc., cost $1,500 more.
Concrete cableway	825	64	....	$ 4,200	
Dam No. 4, Ohio River	1485	103	....	$ 6,500	2¼ in. cable; cost does not include boilers and towers.
Holyoke Dam.....	1615	20–100	50	....	2 in. cable.

Marine, Rock-Transporting Cableway. The following notes appeared in *Engineering News*, Dec. 8, 1910.

The problem was to excavate into a solid hill of granite and to load this stone on barges which, on account of the shoals, could not anchor nearer than 600 ft. to shore. For the work, the contractors, Messrs. Fraser & Chalmers, Ltd., of London, England, called in the Lidgerwood Mfg. Co., of New York, and this firm designed and built the plant described herein. The transporting plant consists of a so-called "quarry cableway,"

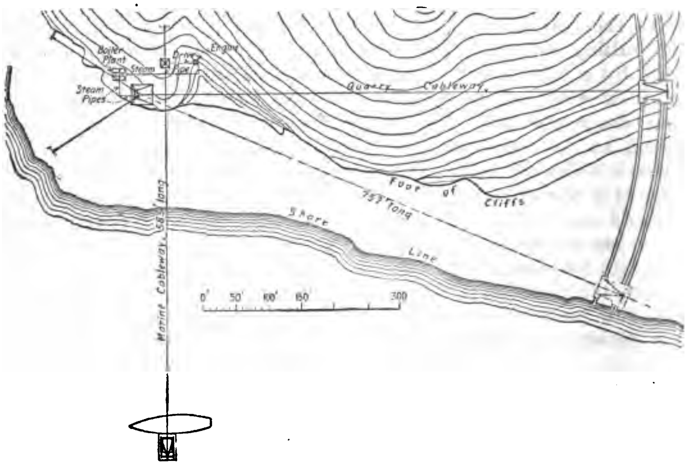


Fig. 73. Layout of Rock Transporting Plant on the Desert Island of Kalagouk, Bay of Bengal.

paralleling the rock face, and a "marine cableway," crossing the former at right angles and reaching to a fixed tower alongside of which the transporting barges anchor. The quarry cableway consists of a fixed pivotal head tower 85 ft. high and a traveling tail tower 74 ft. high, moving on radial tracks through a 48° arc. The cable is 840 ft. long, and the distance between towers is 757 ft. 7 in. The marine cableway has a 30-ft. head tower and a cable extending 585 ft. out into the sea to a 64-ft. tail tower built on piling driven into the soft bottom. These marine towers were built on the "duplex" plan so that if necessary a second parallel cableway might be added if required. Both cables are

controlled from a steam boiler plant, shown on the drawing, from their head towers on shore near the plant.

In operation the broken rock is loaded by hand labor on the open skip traveling on the quarry cableway. The skip is then pulled in towards the head tower and dropped immediately under the marine cableway, where it is picked up by the carriage and

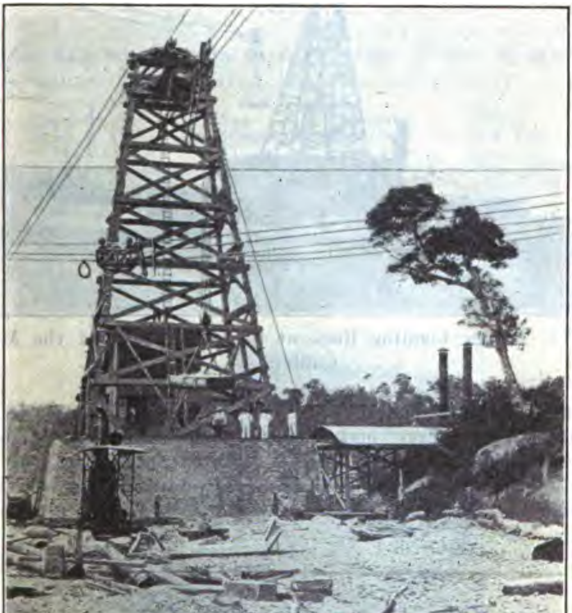


Fig. 74. Head Tower of the Quarry Cableway.

(Showing the skip on the quarry line and the dumping carriage on the marine line at right angles to it.)

swung out on the marine cableway to the barge. These skips measure 8 × 8 × 2 ft. and carry approximately 5½ tons, with each load. The carriage speed upon the cables is 1,000 to 1,200 ft. per min., and the hoisting speed is 200 ft. per min. The main cables are of locked wire rope 2¼ in. in diameter.

Fig. 74 shows the head tower of the quarry cableway with the boiler house in the background. Crossing at right angles to

the cableway from this head tower may be seen the marine cableway with its traveling carriage in air. Fig. 75 shows the tower at the ocean end of the marine cableway. It was necessary to have at least 20 ft. of water here, and as there is a 20-ft. tide the base of the tower proper had to be at least 40 ft. above

Fig. 75. Barge Loading Rock at the Tail Tower of the Marine Cableway.

bottom. The additional 13 ft. to the tower deck, in order to clear the deck of the barge, makes a very high structure, which had to be thoroughly interbraced. It will be noted that the head piece is provided in duplicate, in case additional service is required.

SECTION 18

CARS

Double Side Steel Dump Cars. A make of cars of this type cost as follows: (Fig. 76)

Capacity in cu. ft.	Gauge in inches	Approximate weight, lb.	Price f. o. b. Pa.
18	18	785	$110
18	20	785	110
18	24	785	110
27	24	880	125

A cradle double-side steel dump car having a capacity of 36 cu. ft., weighs about 1,200 lb. and costs $165 f. o. b. Pennsylvania.

A rocker double side steel dump car of 2 cu. yd. capacity, 38-in.

Fig. 76.

gauge, weighs approximately 2,400 lb. and costs $290 f. o. b. Pennsylvania.

Another make of double side rocker dump cars is as follows:

Capacity in cu. ft.	Approximate weight in lb.	Price f. o. b. Cleveland
18	710	$ 90
28	1230	125
30	1690	145

A rocker dump car of all steel construction costs as follows, f. o. b. Aurora, Ill.

Capacity in cu. ft.	Gauge in inches	Approximate weight in lb.	Price
18	18	975	$116
27	24	1100	144
40	30	1645	200

A make of rocker dump cars equipped with end lock that will automatically lock itself in three positions, and with roller bearings, costs as follows: (Brakes can be furnished if desired at an extra cost.)

Capacity in cu. ft.	Net weight in pounds	Price f. o. b. factory
18	960	$155
27	1000	175
36	1315	190
40	1526	200
54	1900	235

In excavating a bank of hardpan with a 14-ft. face in 1907, the following equipment and men were used:

10 steel double side dump cars, 36 cu. ft. capacity, 36-in. gauge at $72.50	$ 725.00
2 brake cars at $92.50	185.00
2 switches complete at $30.00	60.00
1,500 ft. of 30-lb. rail and plates, etc. = 600 ft. of track and 1 turn-out at 19 ct. per ft.	285.00
200 ties, 6"x 4" spruce, 5½ ft. long	49.50
Spikes and bolts	40.00
Total cost of plant	$1,344.50
1 foreman at $3.00	$ 3.00
6 pick and bar men at $1.50	9.00
12 shovelers at $1.50	18.00
1 horse and driver at $3.50	3.50
½ trackman at $1.50	.75
1½ dumpmen at $1.50	2.25
Total labor cost per 10 hours	$ 36.50

The earth, which was extremely hard, was undermined and pried down with picks and bars, and loaded into a train of six cars. The whole gang then started the train, which ran down the 4% grade to the dump by gravity. After being dumped, it was hauled back by one horse. Thirty-three trains or 198 cars, well loaded, per day, was the output. A car was found to contain about 1 cubic yard of earth place measure. This gives a labor cost of about 18.5 cents per cubic yard. About $1.75 per day was spent on repairs to the equipment.

On another job two trains of ten cars each were used. The gang was as follows:

1 foreman	@	$3.50	$ 3.50
20 loaders	@	1.50	30.00
1 dump foreman	@	1.60	1.60
3 dump men	@	1.50	4.50
2 brakemen	@	1.60	3.20
1 trackman	@	1.60	1.60
2 pickmen	@	1.50	3.00
1 waterboy	@	1.00	1.00
2 extra men	@	1.50	3.00
1 hauling team and driver	@	5.00	5.00
1 plow team and driver	@	5.00	5.00
Total			$61.40

The earth was of hardpan and sand and the cut ranged from 0 to 15 feet. The fill was about 9 feet in height. The average haul was 800 feet. Thirteen hundred feet of track was laid at a cost of $75. The average daily output was 330 cars, or yards, making a labor cost of about 19 cents per yard.

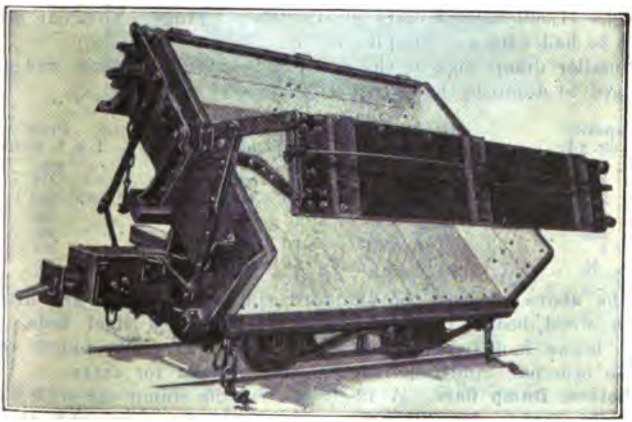


Fig. 77.

Cars similar to these were loaded by a 30-ton traction shovel for 10 cents (contract) per yard, and dumped and hauled back by horses for 7 cents per yard, average length of haul 1,500 feet. The repairs on cars were very high, amounting to about 4 cents per yard.

Two-way side dump cars similar to the one shown in Fig. 77, without brakes, cost as follows:

Capacity in cu. yd.	Gauge	Approximate weight in lb.	Price f. o. b. Louisville
1½	24 or 30 in.	1900	$180
2	24 or 30 in.	2400	190
4	36 in	6500	445
6	4 ft. 8½ in.	9200	550

A make of two way side dump cars cost as follows:

Capacity in cu. yd.	Approximate weight in lb.	Price f. o. b. Aurora, Ill.
30	51,000	$5,110
20	44,300	3,840
16	35,000	3,470
12	28,800	2,517
10	14,500	1,187

The above cars with the exception of the 10-yd. size are fitted with air brakes. All these cars have wood beds and are dumped by air. The gauge is standard. These cars are all of standard construction and are built to the requirements of the Interstate Commerce Commission.

An 8-yd. dump car fitted with air brakes and dumped by hand weighs 17,300 lb. and costs $1,549. 36-in. gauge. This car may also be had with air dumping device.

Smaller dump cars of the same make without brakes and arranged to dump by hand cost as follows:

Capacity in cu. yd.	Gauge in inches	Approximate weight in lb.	Price f. o. b. factory
5	36	6900	$630
4	36	6700	597
3	36	4900	423
2	30	2800	228
1½	24	2000	185
1	24	1700	157
½	18	1000	113

The above cars are of standard construction and are fitted with wood beds. They may also be had with steel beds. A foot brake is fitted without extra charge to every fourth car when ordered. Additional brakes are charged for extra.

Bottom Dump Cars. A 12-cu. yd. bottom dump car with oak bed, of standard construction, standard gauge, weight about 18,000 lb., without brakes and arranged to dump by hand, costs $1,794 f. o. b. factory. This car may also be had with air brakes.

A similar car with a capacity of 6 cu. yd. weighs 9,400 lb. and costs $903.

These cars are useful for ballasting purposes, either on electric or steam railroads, for filling in trestles, hauling cinders, coal, gravel, crushed stone, etc.

Standard platform cars with four wheels having frames of steel and platforms of wood cost as follows: (Fig. 78.)

Capacity in tons	Gauge in inches	Approximate weight in lb.	Price f. o. b. Pa.
2	20	482	$65
2	24	490	65
2	20	500	65
2 to 3	24	560	65
2 to 3	24	600	65
2	24	590	75
2 to 3	24	650	75
2 to 3	24	690	75
2 to 3	30	750	75
2 to 3	36	900	95

In the above table the cars priced at $65 have platforms 5 ft. by 36 in., those priced at $75, have platforms 6 ft. by 48 in. and the one at $95, 8 ft. by 60 in.

Fig. 78.

Platform cars of another make cost as follows:

Steel Tops or Wood Tops

Capacity in tons	Gauge in inches	Net weight in pounds	Price f. o. b. factory
1½	24	493	$ 90
3	30	903	125
5	36	1168	135

Flat cars of still another make cost as follows:

Capacity in tons	Gauge in inches	Approximate weight in lb.	Price f. o. b. Aurora, Ill.
2	24	1100	$113
5	36	3400	214
6	36	3900	332
8	std	5300	487
10	std	6800	572

Revolving dump cars (Fig. 79) used for transportation of concrete, wet sand, mortar and other wet material cost as follows:

Capacity in cu. ft.	Gauge in inches	Approximate weight in lb.	Price f. o. b. Pa.
12	18	496	$65
12	20	496	65
12	24	505	65
18	18	555	70
18	20	555	70
18	24	565	70
27	24	640	90

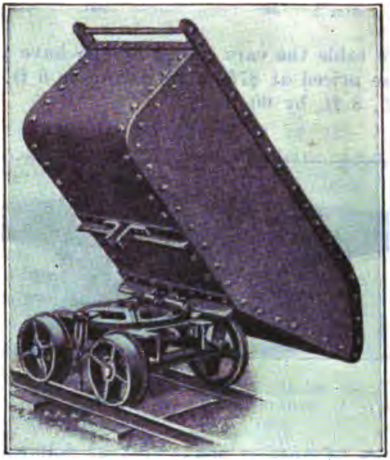


Fig. 79. Revolving Dump Car.

Rotary dump cars, self-dumping, provided with automatic locking device which prevents dumping and rotation while the car is being moved, come in the following sizes:

Capacity in cu. ft.	Gauge in inches	Net weight in pounds	Price f. o. b. factory
15	24	871	$160
22	24	982	170
30	30	1394	200
1½ cu. yd.	36	2256	330
2 cu. yd.	36	2600	380
3 cu. yd.	36	3480	525

Gable bottom cars, designed for use in mines and quarries have bottom sheets with steep angle of slope which insures complete and rapid discharge. Locking levers prevent dumping when car is in motion. Equipped with roller bearings, brakes fitted if desired.

Capacity in cu. ft.	Gauge in inches	Net weight in pounds	Price f. o. b. factory
18	24	1471	$225
27	24	1877	265
40	30	2272	300
54	30	2469	316

Skip Car. This car is designed to be used as an automatic dumping shuttle car between the point where the materials are delivered on the job and the storage bin. The rear wheels are cast with a stepped tread for carrying this end of the car up the discharge rail for automatic dumping.

Capacity in cu. yd.	Gauge inner track	Gauge outer track	Net weight in pounds	Price f. o. b. factory
½	38	46	810	$170
1	48	56	1196	217
1½	56	64	1430	235

Comparative Cost of Handling Earth on Flat and Air Dump Cars. The following appeared in *Railway Age Gazette,* June 18, 1915:

In excavating for the new passenger terminal and belt line at Kansas City it was necessary to remove over 2,000,000 cu. yd. of earth and rock. This material was handled on flat cars and on 12-yd. Western air dump cars. For two months, the cost of handling material with these two types of equipment was carefully compiled. The conditions under which the two kinds of equipment were employed were very similar, the material in each case consisting of at least 75% solid rock. If conditions favored either type of equipment, the advantage was with the flat cars as the interference with traffic was greater at the dump when the air dump cars were used.

The following tabulation gives the relative cost of operation for the two months:

First Month

	Flats	Dumps
Car repairs	$0.0706	$0.0011
Engines	.0821	.0235
Lidgerwood and airmen	.0052	.0067
Labor on cars	.0274	.0087
Labor on track	.0838	.0658
Eng. and super.	.0043	.0043
Miscellaneous	.0102	.0031
Total per cu. yd.	$0.2836	$0.1132

Second Month

	Flats	Dumps
Car repairs	$0.0698	$0.0070
Engine service	.0748	.0243
Lidgerwood and airmen	.0044	.0080

Labor on cars	.0337	.0077
Labor on track	.0926	.0570
Eng. and super	.0036	.0050
Miscellaneous	.0063	.0043
Total per cu. yd.	$0.2852	$0.1133

It will be noticed from the above that there was considerable difference in the cost of car repairs. In justice to the flat cars it should be said that the repairs shown for these two months exceeded the average cost up to that time by approximately 1½ ct. per cu. yd. The flat cars were of wooden construction with capacities of 60,000 lb and 80,000 lb., and had been in constant service for 18 months at the time this information was collected. The dump cars were of steel frame construction, of 80,000-lb. capacity and had been in service five months.

The cost of engine service includes the rental of the engines and the pay of the crews from the time of their arrival to the time of the departure of the trains at the dump. A sufficient track force was always maintained to assure no delays to the trains waiting for the dump tracks to be put into condition. During the two months under consideration the unloading was done in yards exclusively, and for this reason the cost of engine service was not as great as later when the material was unloaded on the main tracks, which carried a traffic of approximately 150 trains per day in addition to many switching movements. Very litle unloading was done on the main tracks by means of a Lidgerwood engine and plow because of the danger of delays both to the construction trains and to traffic. On the other hand trains of dump cars were frequently sent out to unload a few minutes ahead of passenger trains with only slight danger of delaying them.

The third item of cost, that of Lidgerwood and airmen, arose from the fact that it was found desirable to have a mechanic operate the Lidgerwood to reduce delays and for the same reason to have a mechanic with the air dump cars. In addition to taking care of the air valves and pipes, this man also made light repairs on the cars. The expense for labor on the cars was much greater on flat than on dump cars, especially during the winter months, as would be expected because of the difficulty of keeping the car floors and aprons clean to prevent dirt from accumulating and freezing.

The cost of track labor was dependent more on the height of the fill and other conditions than on the type of equipment used. Where it was practicable to use only one track a saving in track labor was effected by the use of the dump cars as they could be

unloaded more quickly and thereby cause less delay to the track laborers. Where two dumping tracks were available this difference did not exist.

While the last two items in the tabulation do not depend on the type of equipment used, it was found that more emergencies arose from the use of flat cars with Lidgerwood unloaders and plows than from the use of dump cars. Also, it was found possible to unload at the end of a spur track on a fill successfully with dump cars, while this could not be done with flat cars and plows since the blow at the end of the train occupied a space of at least 20 ft.

Cars Used in Concrete Plant

Radial Gate Hopper Car used for the distribution of concrete:

Capacity in.cu. ft.	Approximate weight in pounds	Price f. o. b. Cleveland
24	975	$190
32	1065	205

Controllable Bottom Dump Car, mounted on a skeleton truck for placing concrete in forms where a narrow controllable bottom discharge is needed:

Capacity, wet concrete, cu. ft	Gauge in inches	Net weight in pounds	Price f. o. b. factory
12	24	1147	$265
14	24	1190	275
22	30	1582	310
27	30	1649	315
40	30	1900	345
54	36	2400	400

Side and End Dump Hopper Cars. These discharge through controllable radial gates of a size to empty the cars quickly and to handle any aggregates generally used in construction work. The gates are practically grout tight for concrete.

Side Dump Hopper Cars

Capacity, wet concrete, cu. ft	Gauge in inches	Net weight in pounds	Price f. o. b. factory
12	24	930	$157
14	24	946	180
22	30	1414	232
27	30	1500	250
40	30	1555	260
54	30	1618	275

END DUMP HOPPER CARS

Capacity, wet concrete cu. ft.	Net weight in pounds	Price f. o. b factory
12	1014	$184
14	1043	190
22	1519	230
27	1607	255
40	1708	265
54	1808	280

The gauges for these cars are the same as for the side dump.

Side Dump Bucket Cars. This car differs from the hopper car in that the ends of the bucket are vertical, the length of the gate being the full width of the bucket. The longer gate is better in placing concrete which is somewhat stiff, and in handling aggregates, earth, etc. The gate is of the radial type and is made grout tight for concrete.

Capacity, wet concrete in cu. ft.	Net weight in pounds	Price f. o. b. factory
13	997	$260
22	1115	295
27	1586	305
40	1752	345
54	1832	380

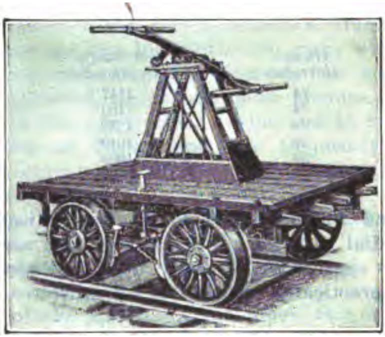


Fig. 80. Hand Car.

Inspection and Hand Cars. Inspection car having platform 6 ft. long by 4 ft. 5 in. wide, with seat for passengers and furnished with either single or double end lever, and hand brake in front of seat to be operated by passengers, weighs approximately 500 lb. and is priced at $80 f. o. b. manufacturers' works.

Hand car, standard gauge, with platform 6 ft. long by 4 ft. 5 in. wide weighing about 575 lb. for shipment, costs $52. One

with platform 8 ft. long by 5 ft. 8 in. wide weighing about 770 lb. for shipment costs $74.

Ordering. In ordering cars or making inquiries from manufacturers the following points should be noted.

Gauge of track.
Weight of rail on which cars run.
Radius and length of sharpest curve.
Style of car (give number of catalog cut nearest to your requirements).
Material to be handled and its weight per cubic foot.
Capacity of car in tons or cubic feet.
Give dimensions of car, if possible.
Any limitations as to height, length or width.
Style of coupling and drawbar.
Distance from top of rail to center of drawbar.
Method of operation — hand, animals, steam or electricity.
Whether to be used singly or in trains.
Number cars to a train.
Diameter of wheels and axles already in use, if new cars are to be used with old ones.
Style of axle boxes, if inside or outside, roller bearings, etc., if with or without springs.
Any other points to be considered.

Depreciation and Repairs. The following tables give the original cost and average repairs per month on about 22,000 cars on a large railroad system. I am indebted to Mr. J. Kruttschnitt for the data from which it has been compiled.

STEEL OR STEEL UNDERFRAME CARS

Type of car	Original cost	No. of cars	Monthly average repairs (About 1910)
Ballast	$ 889.81	460	$ 5.17
Box	1,085.00	2,304	1.57
Coal	674.65	1,594	3.47
Dump	1,461.63	300	4.37
Flat	845.00	2,289	1.05
Furniture	802.29	297	3.61
Gondola or ore	1,210.00	1,419	3.16
Oil	2,110.00	871	10.01
Stock	1,030.00	1,693	1.10

WOODEN CARS

Type of car	Original cost	No. of cars	Monthly average repairs (About 1910)
Ballast	$ 589.09	457	$ 4.78
Box	440.00	6,247	3.92
Coal	557.58	127	3.76
Flat	581.20	512	1.02
Furniture	530.00	278	7.44
Oil	1,800.00	247	13.05
Stock	450.00	2,700	3.61

The average cost of repairs on steel underframe cars was $2.79 and on wooden cars $4.04 per month.

Reports from various railroads indicate that the average cost of repairs of wooden cars varies from $35 to $85 per car per year, and of steel or steel underframe cars varies from $9 to $10 per car per year. The average life of a wooden car is about 15 years, and of steel cars about 25 years.

The cost of repairs on cars per year in percentage of the original cost is as follows:

Type	Steel cars %	Wood cars %
Ballast	7.0	9.75
Box	1.7	10.7
Coal	6.2	8.1
Dump	3.6	..
Flat	1.5	2.1
Furniture	5.4	16.8
Gondola or ore	3.1	..
Oil	5.75	8.7
Stock	1.3	9.6

In the *Railroad Gazette*, October 11, 1907, Mr. William Mahl, comptroller of the Union Pacific and Southern Pacific railways, gives some valuable data as to the life of equipment on the Southern Pacific Railway.

The following are averages for the period of six years, 1902 to 1907, the costs being the average cost per year.

Class	Number serviceable	Expenditure on each per annum: Repairs	Vacated
Locomotives	1,540	$3,165	$183
Passenger cars	1,504	759	104
Freight cars	42,983	70	17

In "repairs" are included the annual expenditure for repairs and renewals of each locomotive or car, other than the expenditure for equipment "vacated." In "vacated" is included the cost of equipment destroyed, condemned and dismantled, sold or changed to another class.

From 1891 to 1907, a period of 17 years, the average number of freight cars "vacated" each year was 3.63 per cent of the total number in service. Dividing 100 by this 3.63, we get 27½, which is, therefore, the average life in years of each freight car. These cars were nearly all wooden cars, of which the cost of a box car did not exceed $450, excluding air brakes.

On the Panama Canal work during the six months ending June 30, 1910, the cost per day of repairs to cars of all kinds

was $1.03. For the same period the cost of repairs to plant and equipment per unit of work done was as follows:

Item	Cu. yd.	Per cu. yd.
Dry excavation	10,515,443	$0.0795
Wet excavation	5,274,633	0.0713
Concrete	565.459	0.1741
Sand	316,028	0 2789
Stone	581,812	0.2410
Dry fill	1,913,963	0.0065
Wet fill	1,556,745	0.0587

The Compartment Type of Rock Car used by the Los Angeles Pacific Railway Co., has proved very successful. In this type of car a box is built on an ordinary flat car having a floor raised about 2 feet along the center line of the car and sloping to each side. This box is divided into twelve or more compartments, each having two doors, one on each side of the car. The teamster drives his wagon along the side of the car and adjusts a board between his wagon and the car which prevents the spilling of any rock on the ground. He then, with his shovel, loosens the hook holding the door in place, which allows it to swing up and discharge the whole two yards which each compartment contains. The whole operation is consummated in about one minute. Mr. H. R. Postle gives the following bill of lumber for building such a box on a 34-foot flat car:

6 — 2 x 4 in. x 18 ft.	12 — 4 x 4 in. x 8 ft.
6 — 4 x 6 in. x 16 ft.	4 — 2 x 16 in. x 16 ft.
60 — 2 x 12 in. x 16 ft.	

Total, 2,643 ft. at $22 per M ft.= $58.15.

He does not give the amount of bolts and iron required, but says that the shop foreman of the railroad told him that each car costs a total of $250.

SECTION 19

CARTS

The following notes are from "Earthwork and Its Cost," by H. P. Gillette:

The method of hauling with one-horse two-wheeled dump-carts is especially adapted to work in narrow cuts, basement excavations, and wherever the haul is short; but in such places wheel scrapers are ordinarily better, unless the haul is over street pavements.

The great advantage that carts possess over wagons is ease of dumping (one man can dump them) and especially of dumping into hoppers, scows, etc. The data of Morris, who kept account of the cost of moving 150,000 cu. yd. of earth with carts, are the most reliable in print. In his work one driver was required for each cart. Trautwine erroneously assumes that one driver can attend to four carts. For the short hauls upon which carts are ordinarily used one driver can attend to not more than two single horse carts. Morris found the average speed to be 200 ft. a minute, and the average load ⅓ cu. yd. (bank measure, equivalent to 0.37 cu. yd. place measure) on a level haul; ¼ cu. yd. on steep ascents, and there were 4 min. of "lost time" loading and dumping each trip. As above stated, the cost of picking and shoveling average earth is one hour's wages per cu. yd., while if earth is loosened by plow the cost of loosening is about $\frac{1}{20}$-hr. wages of team and driver, and the cost of loading plowed earth is ⅔-hr. wages of laborer per cu. yd.

Upon these assumptions, and accrediting a driver to each cart with an average load of ⅓ cu. yd., we have:

Rule. To find the cost per cu. yd. plowing, shoveling, and hauling "average earth" with carts, add together these items:

> $\frac{1}{20}$-hr.'s wages of team and driver and helper on plow;
> ⅔-hr.'s wages of laborer shoveling;
> ¼-hr.'s wages of cart horse and driver for "lost time."

To which add $\frac{1}{20}$ hr.'s wages of cart, horse and driver for each 100 ft. of haul. With wages of a man at 30 ct. and of a horse at 15 ct. per hr., this rule becomes: To a fixed cost of 35 ct. add 2.25 ct. per cu. yd. per 100 ft. of haul.

If one driver attends to two carts, as is very often the case, the hauling item is 1/40 hr.'s wages of a man and two horses, or 1.5 ct. per cu. yd. per 100-ft. haul at wages above given. In cities where streets are level, and hard, even if not paved, one-horse carts holding 2/3 cu. yd. are used; furthermore horses travel faster than the 200 ft. per minute given by Morris on railroad work, 220 to 250 ft. a minute being the speed at a walk over hard level roads. With large 2/3-yd. one-horse carts and one driver to each cart, the cost of hauling per cu. yd. per 100 ft. is therefore, 1/45 hr.'s wages of horse and driver, or 1 ct. per cu. yd. per 100 ft. of haul.

Fig. 81. Two-Wheeled Cart.

Cost with Carts. *Engineering and Contracting*, Jan. 22, 1908, gives the following:

The job was earth excavation in the construction of a railroad. A cut was taken out with carts, which were loaded by men using short handled shovels. The work was done in the late fall and early winter, when a fair amount of rain fell, but snow falls did not occur. At night the ground froze to a depth of a few inches, and was generally thawed out by the sun during the day. This made the runway muddy and made some of the shoveling harder. The material was red clay that readily absorbed water. The average length of the haul was 900 ft.

The earth was loosened by picks, two pickers keeping three shovels going. Three men shoveled into a cart, two carts being loaded at one time. Four carts were used, one driver attending to two carts, which he took to the dump together. One man on the dump, with the aid of the driver, dumped the carts.

The wages paid for a 10-hr. day were as follows:

Foreman	$3.50
Laborers	1.50
Water boy	1.00
2 carts and 1 driver	4.50

The cost per cubic yard of doing the work was:

Foreman	$0.050
Picking	0.080
Shoveling	0.130
Dumping	0.021
Water boy	0.014
Hauling	0.110
Total	$0.405

The output of this gang per day was 70 cu. yd. This is a high cost, as a greater yardage should have been excavated. The pickers loosened about 18 cu. yd per man day, while about 11 cu. yd. per man day were shoveled. The man on the dump took care of 70 cu. yd. per day. A careful analysis of this and a comparison of costs of similar work show that the cost of hauling is a little low, while the other costs are all high. This leads to the conclusion that there were not enough carts for this length of haul.

As the foreman was experienced and realized that he was short of carts, he did all he could to keep them going continually and loaded them as heavily as the ground over which he had to haul would permit. The result was that he worked the horses harder than they are ordinarily worked, as will be noticed from the cost of hauling, which was 11 ct. for a distance of 900 ft. With the wages given above, the cost of hauling per 100 ft. with carts would be about 1 ct., and adding to this the lost team time the total cost should have been for a 900-ft. haul about 12 or 13 ct., while the cost, as stated, actually was 11 ct. That the foreman did his work well is evident from the fact that with a lack of carts that was bound to make his men idle at times waiting for the carts to come back from the dump, he got an output of about 11 cu. yd. from his shovelmen per day.

If two more carts had been used, the shovelers could no doubt have loaded 14 cu. yd. to the man, and instead of using only three men loading to the carts four men could have been employed. This would have made the output per day 112 cu. yd. instead of 70. Thus a saving on the total cost of nearly 20% could have been effected.

With the material that had to be excavated, a man could readily loosen with a pick, by caving in a bank, from 25 to 30 cu. yd per day, and a man could load into a cart with a shovel 14 cu. yd. The dumpman could easily have cared for the 112 cu. yd. that were sent to the dump.

The costs as given illustrate in a striking manner how one detail of a job that is not properly managed can materially increase the cost of all the other details and that of the whole job and yet that particular cost may be low. Such facts can only be learned by keeping detail cost data and then carefully analysing them.

A contractor's dump cart, body made of white oak, ironed and braced, white oak wheels, tire size 3 by ½ inch, height of wheels 5 ft., body size 3 ft. wide, 5 ft. long, 1 ft. deep, weighs complete

Fig. 82. Grout Cart.

660 lb., price $75. The end board lifts out and by releasing the box at front end, dumps automatically.

Brick Cart. This is designed for hauling heavy material and is made of hard wood throughout. This cart has a bed of 5 ft. length, depth of 26 inches, width at bottom of 3 ft. 9½ in., flare board 12 inches wide; capacity 36½ cu. ft.; wheels 54 inches high. Approximate weight 1,000 lb., price $95 f. o. b. Aurora, Ill.

Trash Cart. Similar to the above but of lighter construction. Capacity 36½ cu. ft., weight approximately 800 lb., price $91.

Pick-up Carts or beam trucks, having two wheels and a raised

axle, are used for picking up and hauling iron pipe, timbers, structural shapes, etc.

They are usually drawn by hand.

Diameter of wheels, 40 in.; weight, 400 lb.; price	$100
Diameter of wheels, 48 in.; weight, 450 lb.; price	103
Diameter of wheels, 54 in.; weight, 500 lb.; price	115

Grout Cart. A cart similar to the one shown in Fig. 82 is designed so that the paddle wheels, which keep the grout well mixed, are on the same axle as the wheels proper and revolve

Fig. 83.

with them. The price of this cart is $55 f. o. b. distributing point.

Concrete Carts. These carts have two wheels and are made of steel.

Concrete capacity in cu. ft.	Weight in pounds	Gauge	Wheel diameter	Price
4½	170	14	30	$30
6	188	14	30	32
6	196	14	36	34
6	246	14	42	40

A patented gasoline truck fitted with an automatic dump body, Fig. 83, has a capacity of 1 cu. yd. of dry mix or 18 cu.

ft. of wet mix. It has an all-metal body of the hopper type and automatically spots and dumps its load in any desired place. It will take wet mix directly from the central mixing plant to the roadway or dry mix from the storage pile or bin to the mouth of the mixer without rehandling. It is equipped with wide faced steel wheels to prevent cutting up the finished subgrade. It has three wheels, the load being carried by the two front driving wheels and the steering being done by the single wheel in the rear. It operates at speeds of from ½ to 12 miles per hr., with an average gasoline consumption of 3 gal. per day. This machine weighs 2,400 lb., and costs about $1,700 f. o. b. factory.

SECTION 20

CEMENT GUN

The cement gun is illustrated by Fig. 84. It has two chambers, the upper being fitted with a hopper and containing two bell valves, the lower containing the feed wheel, air motor, and air jet. It is mounted on wheels so that it may be readily moved as the work progresses. The standard equipment consists of 50 ft. of material hose, 50 ft. of air hose and 50 ft. of water hose, together with complete nozzle having water valve and water connection. These machines may be had in the following sizes:

Capacity in sq. yd.	Air pres., lb. per sq. in.	Cu. ft. free air per min.	Weight in lb.	Approximate Price
100 to 125	35 to 50	100	1,200	$1,300
150 to 160	35 to 50	150 to 160	1,400	1,400
200 to 250	40 to 60	225	1,600	1,500

The above capacities are based on a surface 1 inch thick in 8 hrs.

Operation. The following notes on the operation of the cement gun were by Mr. Byran C. Collier.

In operating, the material is first mixed dry, and placed in the upper chamber of the machine from which it travels in consecutive stages to the lower chamber, and thence through the hose to the nozzle. It is well to bear in mind that a normal percentage of moisture in the sand (4% to 6%) is advantageous, as otherwise there is too great a tendency of the sand and cement particles to be segregated. The water is introduced through the walls of the nozzle in needle jets under higher pressure than the air, thereby causing these jets to puncture this stream of flowing material. The action of the air in the main hose causes the water from these jets to become atomized, resulting in the covering of all the particles with this fine spray. When this hydrated material is impelled against the surface to be coated the first effect is to cause a very marked rejection of material, which, examination has shown, is sand only, showing that the cement has adhered to the surface forming a film of neat cement which acts as a matrix. When this matrix assumes a perceptible

thickness the sand finds a seat, and the rejected material grows markedly less. There continues a certain amount of rejection of this inert material, each grain of which, however, has performed the function of acting as a tamper to drive the preceding grains deeper into the matrix in which they are seated. The result of this pounding action is to produce a very dense, hard and durable mortar.

Although this "rebound" has a definite and useful action, it also presents a difficulty which must at all times be reckoned

Fig. 84. Cement Gun.

with in order to insure proper and satisfactory work. It is the custom to use air at a pressure of about 35 lbs. at the "Gun" under normal conditions of operation, and with from 50 to 100 feet of hose in use. This will mean that the impelled material will have sufficient velocity to result in the "rebound" being thrown back sufficiently to clear the reinforcing wires. If, on the other hand, too low pressure is used this rebounded material lacks sufficient velocity, and causes it to fall behind the reinforcing wire in loose piles forming what are termed "sand pockets." In

cases where the material is "shot" into confined spaces similar conditions will arise unless care is exercised and methods developed to overcome this.

Cost of Cement Gun Work at the Elephant Butte Dam. The following notes from *Compressed Air Magazine,* May, 1916, illustrate very well the detailed manner of cement gun operation.

The upstream face of the Elephant Butte dam of the United States Reclamation Service was waterproofed with portland-cement mortar mixed in the proportion of one part cement to two parts sand and applied with a cement gun in a coating about 1 in. thick. Advantage was taken of rising water in the reservoir to work from rafts specially constructed for the purpose. There were two of these, each 9 x 13 ft., made of planking on a framework laid on and attached to 16 oil barrels. One raft contained the machine, operator and helpers, small mixing box and a few sacks of cement and sand, while the other was loaded with cement and sand.

The coating was applied in horizontal strips about 10 ft. high and the length of the dam at water level. The surface was first cleaned thoroughly with scrapers and wire brushes and then gone over with a sand-blast, using coarse sand, passed through the machine to obtain the necessary pressure. This roughened the surface sufficiently to cause the mortar to adhere to it. The surface was then thoroughly moistened with a hose and the mortar immediately applied. The mortar was put on in four layers, each about ¼ in. in thickness. It was found that a thicker coat than this applied on a vertical wall, without reinforcement, would, on account of its weight, slough off before setting. Each layer followed the preceding one before it had attained its final set. Numerous samples taken from the face showed perfect adhesion to the concrete, it being impossible in every case to break the mortar from the concrete at the line of contact. The cost per square foot for the first 100,000 sq. ft. of this coating was as follows:

Operating and repair work, including cost of air and water	$0.015
Staging, cleaning wall, moving, etc.	.006
Cement	.024
Sand, including labor, screening and hauling (sand only 20 ct. per cu. yd.)	.007
Depreciation of gun and equipment	.020
Subtotal	$0.072
Overhead	.007
Total cost per sq. ft.	$0.079

Some experiments were also conducted at Elephant Butte to determine the feasibility and probable cost of troweling the mortar

placed by cement gun, with the idea of using the machine for the lining of canals or for repairing lining that had disintegrated and required a smooth finish. The area treated was 75 sq. ft. This was covered with mortar averaging ¾ in. in thickness in 15 min. working time, or at the rate of 300 sq. ft. per hr. for this average thickness. One good finisher troweled 56 sq. ft. in 25 min., or at the rate of 135 sq. ft. per hr. Possibly two men could keep up with the gun. The finishing was not done to a screeded surface. The surface is wavy, but much smoother than a formed surface would be. It could be screeded to a plane, if thought necessary. Care must be taken that too much material is not deposited in one coat, or horizontal cracks will occur, due to settlement. Some cracks appeared in this experiment, and in each one the material was found to be from 1 in. to 1½ in. thick. The cost of this particular experiment, not counting cost of setting up, equipment, etc., was as follows:

Labor	$0.30
Sand, approximately 9 cu. ft.	.90
Cement, 4 sacks	2.00
Total for 75 sq. ft.	$3.20
Per square foot	$0.04¼

Depreciation, staging, moving, etc., would depend on the job, but it is probable that the total cost of placing this coating, including the troweling, under average conditions would not exceed 5c per sq. ft.

In using the cement gun the sand must be clean, sharp and not too fine. It must not be bone-dry, or trouble with feeding will occur. The air pressure should be about 30 lb. in the gun and the water pressure over 60 lb. It has been figured at Elephant Butte that 30 ft. of free air at 100 lb. pressure at the point of delivery to the gun and 10 gal. of water are required per minute.

Cost of Lining a Reservoir with Concrete by the Cement Gun. The following notes by Mr. E. C. Eaton appeared in *Engineering News Record*, July 24, 1919.

The total area to be lined was 114,000 sq. ft., and specifications called for a gunite lining 1 in. in thickness, with a mix of one part of cement to 5½ parts of sand; no lime was used in the mixture. The lining was reinforced with galvanized poultry netting, 1½-in. mesh, No. 19-gage wire, placed in the center of the concrete to confine cracks due to expansion to hair cracks, and no expansion joints were used.

This work was let by contract at a price of 10½c. per square foot, including the trimming and preparation of the banks.

Work was commenced Jan. 14, 1919, and completed Mar. 19. Because the work had to be done during the winter months the actual number of working days in this time was only 39.

The cement gun used was what is known as the N2 size. It was kept on the upper bank of the canal at a maximum distance of 600 ft. from the compressor, to which it was connected with a 2-in. iron pipe. The compressor was of the portable type, direct-connected to a semi-Diesel type of engine; it was 12 x 12 in. and ran at a speed of 300 r.p.m. A pressure of 42 lb. per square inch was maintained at the compressor, giving about 32 lb. at the gun. A 2-in. rubber hose 200 ft. in length was used from the gun to the nozzle, and the rubber tips in these nozzles lasted nearly one week before requiring replacement. The depreciation on the hose for the period of the job was $200.

In lining the 114,000 sq. ft., 2904 sacks of cement were used, or nearly 39 sq. ft. of lining per sack of cement. The average rate of progress throughout the work was 2900 sq. ft. per working day. The maximum day's run was about 5000 sq. ft., though better average progress would have been made in the dry season, as the principal delays were due to wet sand clogging in the hose and necessitating frequent cleaning out of the machine. A certain amount of moisture is necessary in the sand for this class of work, and the best results were obtained when sufficient water was present so that the sand just failed to hold its shape when squeezed in the hand.

The total quantity of sand used on the work was 600 tons, and the total cost of sand per ton was as follows:

	Per ton
Loading charge at sand pit	$0.30
Freight	.60
Unloading	.12
Hauling to site	1.50
Total	$2.52

The hauling over the wet roads a distance of two miles was the biggest item. The weight of a cubic yard of sand, which was wet, was 2,500 pounds.

The cement was $3.45 per barrel delivered at the site, after an allowance of $1 per barrel was made for sacks. The poultry netting delivered at the site cost $1.17 per 100 square feet.

The construction crew employed was as follows:

	Per Day
1 Compressor engineer	$ 7.00
1 Nozzleman	5.00
1 Man placing wire	5.00
2 Mixers at $4	8.00

1 Man loading gun	4.00
1 Nozzleman helper	4.00
1 Gun operator	4.00
1 Man cleaning off rebound	4.00
Total payroll	$41.00

One man was kept continuously close to the nozzleman, his duties being to brush back the rebound at the junction of new and old work and to raise the reinforcement by means of a hook to insure its being placed in the center of the lining.

The fuel used consisted of a fuel oil having a gravity of 27 +. Ten drums of this oil of 104-gal. capacity per drum were used. The cost of the oil was $6.55 per drum, delivered to site. The loss by rebound in percentage of the sand used was 8½; this was not wasted, however, as it was collected, screened and used over again with good results, except that only 30 sq. ft. of lining per sack of cement, or 23% less than with new sand, could be gotten when rebound was used, due to the material being coarse and requiring more cement to fill the voids.

Particular attention was paid to the curing, by sprinkling, of the newly completed lining for a period of two days, and up to this time no cracks other than fine hair cracks have developed.

Cost of Cement Sand Coating. The following costs of cement-sand coating of an experimental mine were taken from an article by Mr. George S. Rice in *The Coal Industry*, Jan., 1918.

For coating 378 feet of entry, averaging 5.9 feet in height and 9.15 feet wide, the cement averaging about 2 inches in thickness on the ribs and ½ inch thick on the roof, the costs were as follows:

Labor and Repairs		
Labor	$138.86	
Supervision	23.04	
Cleaning and repairing gun	10.74	$172.64
Material		
Cement, 280 sacks, or 70 bbl. at $1.10 per bbl.	77.00	
Sand, 42 tons at .89	37.38	114.38
Total		$287.02

The cost per lineal foot of entry averaged 76 cents, and the cost per square yd. of surface averaged 32 cents. This job took 10 days and the speed was 4.7 lineal feet per hour or 11¼ sq. yd. per working hour. In a subsequent job, the total cost per lineal foot of entry was 93 cents and the average cost per sq. yd. was 40 cents.

One of the companies in Pennsylvania reports that the actual cost was $3 per lineal foot of heading. The heading averaged 22 square feet in section, making the cost about 13.6 cents per square foot, or $1.22 per square yard of gunite deposited. This cost is based on cement at about $2.20 per barrel and sand at $2 per ton at the site. The thickness was about one inch, no reinforcement being used; but it was most carefully done and probably includes all costs.

At a mine in the Connellsville district, the cost of cementing 5,229 square feet was accomplished in 12 days, the daily cost was as follows:

One demonstrator	$ 2.86
One nozzleman	2.85
One machine tender	2.15
Two laborers at $2.15	4.30
One-half time teamster at $2.00	1.00
Total	$13.16

The total labor cost was $154.82.

Material

325 sacks cement	$125.12
600 bushels sand	36.00
50 ft. mining machine hose	17.50
Total	$178.62
Grand total	$333.44

The cost per square foot was, therefore, 6.38 cents, or per square yard, 57 cents. It will be observed that these figures vary widely, but it is thought that under average conditions with men fully trained in the use of the cement gun, that work can be done for at least 50 cents per square yard on the basis of wages prevailing prior to 1917.

Information obtained in January, 1918, relative to costs in a Pennsylvania mine:

Main Slope

Trimming and handling rock	$ 70.00
Mixing cement outside	56.50
Labor on cement-gun	156.25
29½ bbl. cement at $1.75	51.63
17 tons sand at $1.50	25.50
	$359.38

Progress 5% lin. ft. of slope or 11,400 sq. ft.= 3 ct. per sq. ft. for thickness ½" to 1".

SECTION 21

CEMENT TESTING APPARATUS

On large concrete jobs it is desirable that all cement shall be tested. The usual practice is to engage a specialist, who sends a representative to obtain samples from the job for testing at his own laboratory. This is undoubtedly the best way, but where work is located far from large cities testing in this manner is very expensive. This difficulty is generally overcome by selecting samples from the cars immediately before they leave the factory and then sealing the cars. On work where these methods cannot be used a field laboratory can be installed.

Such a laboratory, exclusive of the building, water supply, and few pieces of furniture will cost as follows:

1 Cement testing machine with tension attachment	$224.00
1 Percentage scale ½ to 16 oz.; 0 to 100%	9.60
1 Even balance scale with brass weights	14.00
2 Three section gang moulds at $16	32.00
1 Ground glass plate 24 by 24 in.	10.00
1 Galvanized pan 24 by 24 by 3 in. deep	4.00
1 Set Gilmore needles	6.00
1 16 oz. measuring glass	1.00
1 Small trowel	.80
1 Large trowel	1.00
1 Set cement test sieves, 50, 100 and 200, with lid and bottom brass	35.00
1 Set sand test sieves, 20, 30, with lid and bottom, brass	20.00
Total	$357.40

Shipping weight approximately 600 lb.

Where any considerable amount of testing is to be done several more gang moulds with some sort of damp closet are desirable, costing an extra $40 or $50.

SECTION 22

CHAIN BELTS

(See Belting for Power Purposes.)

CHAINS

Chains possess about ⅔ the strength of single bars of iron. They should be very carefully tested, as one weak link means that the whole chain is weak. The diameter of sheaves or drums should not be less than thirty times the diameter of the chain iron used, and for hoisting purposes, chains should be of short links with oval sides. The life of a chain is greatly increased by frequent lubricating and annealing.

B. B. B. Chain is of iron of 48,000 to 50,000 lb. per sq. in. tensility, about 28% elongation in 8 in., and 38 to 40% reduction at fracture.

Special Dredge chain is of iron of 48,000 to 52,000 lb. per sq. in. in tensility, with about 30% elongation in 8 in. and 50% reduction in area. In the following table the safe load should be taken as ⅔ the "proof." The breaking strength is about double the proof.

HAND MADE, HIGH GRADE CHAIN COSTS (APPROXIMATE) PER POUND

Size	Special dredge	B. B. B. crane
½"	$0.22	$0.20
¾"	.185	.17
1"	.155	.14
1¼"	.145	.13

PIPE OR STONE CHAINS WITH HOOK AND RING COST

⅜ inch	12 foot length	$ 8.25
½ inch	12 foot length	10.25
⅝ inch	15 foot length	17.00
¾ inch	15 foot length	21.25

Log Chains, 15′ long, heavy, short link, 7/16″ swivel in center; weight, 30 lbs.; price, $3.25.

	CLOSE LINK CHAIN					STUD LINK					
Size in in.	Average weight per ft. in lb.	Proof test in pounds B. B. B. crane	Proof test in pounds Best special dredge	Outside dimensions in. Length	Outside dimensions in. Width	Average weight per fathom	Outside dimensions in. Length	Outside dimensions in. Width	Proof test, pounds	Breaking strain, pounds	Length six links in.
1/4	3/4	2,000	2,500	1 5/16	7/8	..	...	...	.....	.....	....
5/16	1	3,000	3,500	1 1/2	1 1/16	..	...	...	.....	.....	....
3/8	1 1/2	4,500	5,000	1 3/4	1 1/4	..	...	...	.....	.....	....
7/16	2	6,500	7,000	2 1/16	1 3/8	..	...	...	.....	.....	....
1/2	2 1/2	8,000	9,000	2 3/8	1 11/16	14	3	1 3/4	9,500	15,500	13
9/16	3 1/8	10,000	11,000	2 5/8	1 7/8	18	3 3/8	2	11,750	18,[illegible]	14 5/8
5/8	4 1/3	12,000	14,000	3	2 1/16	24	3 3/4	2 1/4	12,500	22,000	16 1/4
11/16	5 1/3	11,500	17,000	3 1/4	2 1/4	29	4	2 1/2	17,000	28,000	17 1/8
3/4	6 1/6	17,500	20,000	3 1/2	2 1/2	34	4 3/8	2 3/4	20,250	32,000	18 3/4
13/16	7	20,000	23,000	3 3/4	2 11/16	40	4 3/4	3	23,750	36,000	20 3/8
7/8	8	22,000	26,000	4	2 7/8	44	5	3 1/4	28,[illegible]	42,[illegible]	21 1/4
15/16	9 1/6	25,000	29,000	4 3/8	3 1/16	51	5 3/8	3 1/2	31,600	48,000	22 7/8
1	10 1/2	28,000	32,000	4 5/8	3 1/4	59	5 7/8	3 3/4	36,000	54,000	25 1/4
1 1/16	12	32,000	35,000	4 7/8	3 5/16	66	6 1/4	3 7/8	40,600	62,000	26 7/8
1 1/8	13 1/6	36,000	40,000	5 1/8	3 3/4	75	6 1/2	4 1/8	45,500	70,000	27 3/4
1 3/16	14 2/3	40,000	46,000	5 9/16	3 7/8	82	6 3/4	4 1/4	50,750	76,000	28 5/8
1 1/4	16 2/3	44,000	51,000	5 3/4	4 1/8	91	7 1/8	4 1/2	56,250	86,000	30 1/4
1 5/16	17 1/2	48,000	54,000	6 1/8	4 1/4	100	7 3/8	4 5/8	62,000	91,000	31 1/8
1 3/8	19 2/3	53,000	58,000	6 7/16	4 9/16	110	7 3/4	4 7/8	68,000	102,000	32 3/4
1 7/16	21 1/8	58,000	62,000	6 11/16	4 3/4	120	8 1/8	5 1/8	74,250	112,400	34 3/8
1 1/2	23	62,000	67,000	7	5	132	8 1/2	5 3/8	81,000	118,000	36
1 9/16	25 1/8	66,000	70,500	7 3/8	5 5/16	[illegible]	[illegible]	[illegible]	87,900	[illegible]	[illegible]
1 5/8	28	72,000	77,000	7 3/4	5 1/2	150	9 1/4	5 7/8	95,050	134,000	39 1/4
1 11/16	30	75,000	79,000	8 1/8	5 11/16	162	9 5/8	6	102,[illegible]	[illegible]	40 7/8
1 3/4	32	78,000	83,000	8 1/2	5 7/8	175	10	6 1/4	110,250	156,000	42 1/2
1 13/16	33	84,000	89,000	8 7/8	6 1/16	188	10 1/4	6 1/2	118,250	166,000	43 3/8
1 7/8	35	90,000	95,000	9 1/4	6 3/8	200	10 1/2	6 3/4	126,500	178,000	44 1/4
1 15/16	38	95,000	101,000	9 5/8	6 9/16	215	10 3/4	7	135,000	190,000	45 1/8
2	40	102,000	108,000	10	6 3/4	229	11 1/8	7 1/4	144,000	202,000	46 3/4
2 1/16	43	108,000	115,000	10 3/8	6 15/16	243	11 1/2	7 1/2	153,000	216,000	48 3/8
2 1/8	47	115,000	122,000	10 3/4	7 1/8	258	12	7 3/4	162,500	228,000	50 3/4
2 3/16	50	121,000	129,000	11 1/8	7 5/16	273	12 1/2	8	172,250	[illegible]	53 1/8
2 1/4	53	128,000	136,500	11 1/2	7 5/8	289	13	8 1/4	182,250	256,000	55 1/2
2 3/8	58 1/2	140,000	152,000	11 7/8	8	320	13 1/2	8 3/4	203,000	[illegible]	57 1/4
2 1/2	..	......	......	..	..	355	14	9	225,000	316,000	59

Strength and Weight of Close Link Crane Chains, and Sizes of Equivalent Hemp Cables (Unwin).

Diameter of iron in inches	Weight in lb. per fathom	Breaking strength in tons	Testing load in tons	Girth of equivalent rope in in.	Wt. of rope in lb. per fathom
¼	3.5	1.9	.75	2	1⅜
5/16	6.0	3.0	1.1	2½	1½
⅜	8.5	4.3	1.6	3¼	2¼
7/16	11.0	5.9	2.3	4	3¾
½	14.0	7.7	3.0	4¾	5
9/16	18.0	9.7	3.8	5½	7
⅝	24.	12.0	4.6	6¼	8½
11/16	28.	14.6	5.6	7	10½
¾	31.5	17.3	6.8	7½	12
13/16	37.	20.4	7.9	8¼	15
⅞	44.	23.1	9.1	9	17½
15/16	50.	26.1	10.5	9½	19½
1	56.	29.3	12.	10	22
1⅛	71.	36.3	15.3	11¼	27¾
1¼	87.5	44.1	18.8	12½	34½
1⅜	105.8	52.8	22.6	13¾	41½
1½	126.	62.3	27.	15	49½

Strength and Weight of Studded Link Cable (Unwin)

Diameter of iron in inches	Weight in lb. per fathom	Breaking strength in tons	Testing load in tons	Girth of equivalent rope in in.	Wt. of rope in lb. per fathom
⅝	24.	9.5	7.	6½	9
11/16	28.	11.4	8.½	7½	12
¾	32.	13.5	10.½	8	14
⅞	44.	20.4	13.¾	9½	19½
1	58.	24.3	18.	10½	22½
1⅛	72.	29.5	23.¾	12	30¾
1¼	90.	38.5	28.½	13½	39¼
1⅜	110.	48.5	34.	15	48¼
1½	125.	59.5	40.½	16	55
1⅝	145.	66.5	47.½	17	62
1¾	170.	74.1	55.⅛	18	68¼
1⅞	195.	92.9	63.¼	20	86
2	230.	99.5	72.	22	104
2⅛	256.	112.0	81.¼	24	124
2¼	285.	126.0	91.⅛	26	145

SECTION 23

CHAIN BLOCKS

For moving loads vertically where great power is not obtainable and speed is not a requisite, chain blocks are the best means. These are made in three types, spur geared, screw geared and differential.

Spur Geared Blocks

Capacity in tons	Hoist in ft.	Weight, lb. (Net)	Price	Extra hoist per ft.
½	8	53	$ 70.00	$ 1.80
1	8	80	90.00	1.90
1½	8	124	120.00	2.00
2	9	188	140.00	2.10
3	10	200	180.00	3.00
4	10	290	220.00	3.20
5	12	380	280.00	4.30
6	12	390	330.00	4.30
8	12	470	400.00	5.40
10	12	570	480.00	6.50
12	12	800	600.00	8.60
16	12	1,000	720.00	10.80
20	12	1,375	850.00	13.00

Sizes 3 to 20 tons have a lower as well as an upper block.

Screw Geared Blocks

Capacity in tons	Hoist in ft.	Weight, lb. (Net)	Price	Extra hoist per ft.
½	8	43	$ 50.00	$2.50
1	8	57	60.00	2 60
1½	8	76	80.00	2.70
2	9	104	100.00	2.80
3	10	200	150 00	3.00
4	10	225	190.00	3.80
5	12	340	280.00	4.00
6	12	360	360.00	5.60
8	12	390	420.00	6.00
10	12	570	550.00	6.40

Differential Blocks

Capacity in tons	Hoist in ft.	Weight, lb. (Net)	Price	Extra hoist per ft.
¼	6	22	$ 36.00	$4.80
½	7	30	42.00	4.80
1	8	51	56.00	5.00
1½	8½	81	72.00	5.40
2	9	122	90.00	5.60
3	9½	180	120.00	6.00

Fig. 85. Chain Block in Use.

Chain blocks kept well oiled and kept under cover where grit and dirt cannot enter the gears should have a life of from five to twenty years. On outside work where sand and grit is allowed to enter the gears the life of a block is reduced very much, and repairs may cost as much as 50% of the first cost annually.

SECTION 24

CHUTES

Chutes for stone or, in fact, almost any material must be lined with sheet iron or steel to prevent excessive wear. Sooner or later a hole wears in these sheets and it is then necessary to renew the entire piece.

Witherbee, Sherman & Co., at Mineville, N. Y., use bar steel for lining their ore chutes. The bars are ¾ x 6 inches in size, and when worn are replaced by a new piece. In this way no steel is wasted and the time spent in repairs is much lessened.

Dolese & Shepard, in their stone-crushing plant in Chicago, at all points where the crushed stone drops, have made pockets where a certain amount of the material collects, and saves the chutes and bins from excessive wear at these points.

Angle Extension Wagon Chutes for hard and soft coal may be economically used in construction work for placing concrete and transporting other materials. They are adapted to indefinite extension, but each section is in itself an independent chute. The prices of chutes 18 in. wide at top and 17 in. at foot, made of No. 18 black sheet steel with heavy end bands, weighing about 5½ lb. per foot, are as follows:

5 ft. lengths, each	$4.00	10 ft. lengths, each	$ 8.25
6 ft. lengths, each	5.00	12 ft. lengths, each	10.25
8 ft. lengths, each	7.50		

CAR CHUTE

A chute constructed of sheet steel and angle iron so as to hook on any car or wagon is made in three stock sizes and in many cases effects great saving in the cost of unloading material from cars. (See Fig. 86.)

This chute is manufactured in two sizes. The 1 cu. yd. size weighs approximately 385 lb. for shipment and costs $60. The 1½ cu yd. weighs about 410 lb. for shipment and costs $70.

A loader used for unloading cars to trucks or wagons, having a capacity of 30 cu. ft., is made in two parts, the bowl and frame. It weighs about 400 lb. for shipment and costs $65 f. o. b. New

York State. The manufacturers give the saving on a job by the use of these loaders as follows: Before the loaders were put into use the time for a round trip per truck was 1 hr. 30 min. By use of the loaders, four of them, the 5-ton truck made the round trip in one hour, a time saving of 33⅓%, an increase in deliveries of 50% reducing the lost time to a minimum and increasing the earnings almost $22 daily.

Car Chute. The following description of a home-made device appeared in *Engineering News Record*, May 15, 1919.

Fig. 86. Car Chute.

It consists of a simple box made of old lumber and measuring about 5 x 7 ft. in plan by 1 ft. 6 in. deep. It holds about 2 cu. yd. of material and loads a motor truck by one operation in a few minutes. The box is arranged to rest on the side of the open railroad car in which the material is received, is slightly overbalanced outward, and is dumped by the release of a rope at the end of a lever at its back, which is fastened to the opposite side of the car.

On the job where this was used it took as long to fill the truck by the ordinary hand shoveling as was required for the truck to make a complete round trip. The device, therefore, practically doubled the number of trips per day for each truck. Furthermore, the loading laborers were continually busy filling the box and did not lose time waiting for the truck to come alongside of the car.

SECTION 25

CONCRETE PLACING EQUIPMENT

A Boiler Hoist Bucket that automatically places itself under the mixer at the bottom of the tower to receive the concrete and delivers it with the same automatic movement into the receiving hopper at the top, costs as follows:

Capacity in cu. ft.	Weight in pounds	Price f. o. b. factory
12	564	$145
24	774	200
36	969	240
54	1572	300

This bucket is used where a large amount of concrete work is to be done with the hoist bucket permanently fixed at one tower position, such as work on bridges, dams, viaducts and all construction where the height is limited.

Quick Shift Hoist Buckets used in building construction and work of considerable height where it is necessary to change the position of the tower hopper cost as follows:

Capacity in cu. ft.	Weight in pounds	Price f. o. b. factory
12	993	$285
24	1213	310
36	1433	340
54	2095	450

Vertical Back Receiving Hopper. This hopper is used in connection with plants employing chutes for taking the concrete away from the hopper proper.

Capacity in cu. ft.	Weight in pounds	Price f. o. b. factory
18	445	$135
36	608	175
54	815	225
80	1144	325

Extended Gate Receiving Hopper. This hopper is used where it is necessary to carry the concrete away from the hopper by carts or cars.

Capacity in cu. ft.	Weight in pounds	Price f. o. b. factory
20	485	$175
30	587	200
40	767	225
60	898	285

Floor Receiving Hopper to be placed on the floor to charge carts or cars for local distribution, that may also be used as a charging hopper for the hoist bucket at a relay point, costs as follows:

Capacity in cu. ft.	Weight in pounds	Price f. o. b. factory
20	663	$185
30	690	210
40	1020	265
60	1260	320

Material and Hopper Bin Gates cost as follows:

Size in inches	Weight in pounds	Price f. o. b. factory
8 by 12	50	$29.60
12 by 18	112	51.00
12 by 12	134	35.40
16 by 16	212	50.00
20 by 20	287	61.00

Tower Sheave Sets cost as follows:

Top

Diameter of sheave in inches	Weight in pounds	Price f. o. b. factory
12	86	$17.00
14	114	27.00
16	134	36.00
18	230	45.50

Bottom

Diameter of sheave in inches	Weight in pounds	Price f. o. b. factory
12	125	$24.00
18	226	45.00

Sliding Frame Fixtures for Quick Shift Plants. These can be applied to either steel or wooden towers and are designed so that quick change of the position of the receiving hopper may be effected.

	Weight	Price
Hopper sliding frame for wood or steel towers	481	$105
Wood tower boom plant sliding frame	1384	320
Steel tower boom plant sliding frame	2353	370

Chutes. A type of chute section used in concrete placing equipment having a hopper at the receiving end, and an apron at the discharge end, is as follows:

Length in ft.	Weight in lb.	Price
10	339	$ 60
20	507	83
30	705	110
40	1060	163
50	1466	216

These sections may be had in various lengths as above, with flanges, hoppers, joints or aprons at the ends. A line gate for the above sections weighs 263 lb. and costs $70.

Another type of chute section having elbows at the ends instead of hoppers and aprons, is made in the same lengths as those above and costs about $12 more for each length. It may be had with elbows flanges and joints at the ends. Boom sections of this type cost as follows:

Length in ft.	Weight in lb.	Price
20	600	$135
30	1200	225
40	1600	291
50	2000	354

Continuous Line Chutes are made in lengths as follows, with flanges on the receiving end, and joints on the discharge end.

Length in ft.	Weight in lb.	Price
10	211	$30
20	379	53
30	577	80

A two wheel trolley to support these chutes weighs 40 lb. and costs $10.50.

Line Gates may be set in the continuous line chutes from which distributing sections of the above type may be run. A line gate in a 10-ft. section fitted with a flexible joint weighs 322 lb. and costs $80.

Flexible Chute Sections can be used where the concrete is to flow in vertical or nearly vertical lines. They are connected together with chains.

Length in ft.	Weight in lb.	Price
2	22	$ 6.75
3	29	7.50
4	39	8.50
5	48	10.00

A three-ft. section fitted with a 24 by 24-in. hopper weighs 80 lb. and costs $20.00.

Flat Bottom Tapered Chute Sections are made in two standard

lengths. The 8-ft. length weighs 140 lb. and costs $20. The 20-ft. length weighs 280 lb. and costs $40.

HOISTING TOWERS

Heavy Steel Towers for roller hoist buckets are made in a wide variety of sizes. A few of these are given as follows:

Height in ft.	Capacity for continuous chute in ft.	Price f. o. b. factory
60	825	$ 970
100	745	1,520
160	650	2,330
200	740	3,045

Light Building Steel Towers for quick shift hoist buckets are as follows:

Height in ft.	Capacity for continuous chute in ft.	Price f. o. b. factory
60	425	$ 760
100	350	1,230
140	275	1,640

Steel towers of the light type having a rated capacity of ½ yd. for use with the buckets, hoppers and chutes of the concrete placing plant are as follows:

Height in ft.	Weight in lb.	Price f. o. b. Ohio
30	2680	$ 445
60	4580	725
90	6620	1,045
120	8660	1,365
150	10560	1,645

Steel towers of one yard capacity are made in the same sizes as the above and cost from $55 to $125 more for each height. Towers of heights other than those shown above may be had at prices in proportion to the height.

A Movable Wooden Tower was used for placing the concrete in a grand stand built at the University of Chicago. The grand stand was 484 ft. long by 114 ft. wide, and it was necessary to move the tower four times in order to place all the concrete. The tower was 72 ft. high and 8 x 8 ft. in section (See Fig. 87). A ¾-cu. yd. mixer was set on the bottom framework of the tower so that it would discharge into a bucket, which in turn elevated the concrete to a hopper on the side of the tower, 60 ft. above. The chutes were of the open-trough type, 10 x 12 in. in size, of galvanized iron, and were suspended from cables run from the tower over the grand stand. The tower was placed on 6-in. wooden rollers placed on a plank runway, power for moving being sup-

plied by a cable from the hoisting engine. Six men were required to place rollers, runway and cables while moving. A move of 50 ft. occupied about 4 hours. The cost of the tower, including labor and material for erection and labor for dismantling was about $600 (about 1910 prices).

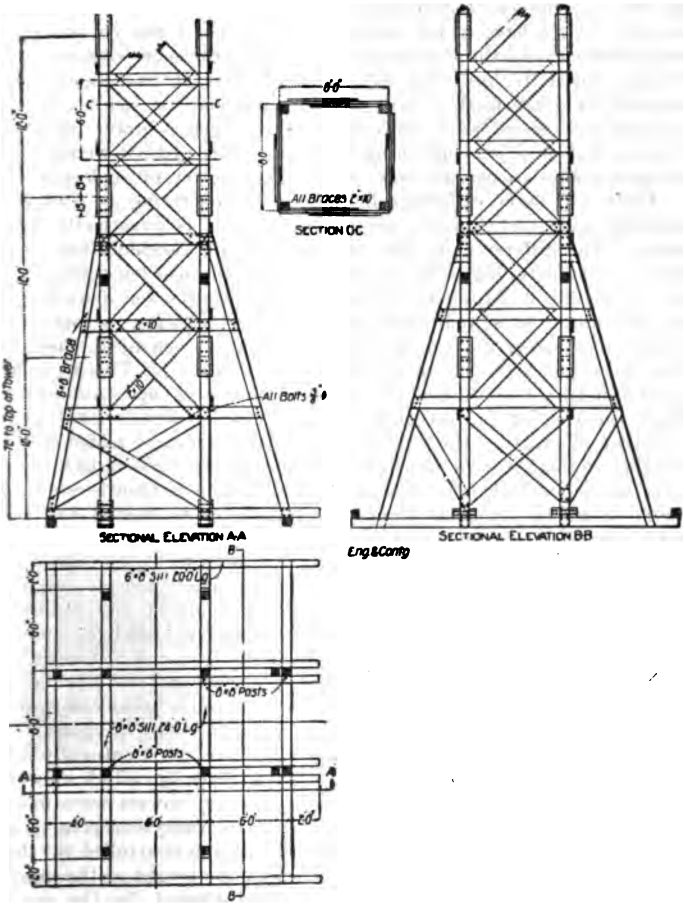


Fig. 87. Movable Wooden Tower for Concrete Chuting System.

COMPARISON BETWEEN TOWERS OF STEEL AND WOOD

The cost of a wooden tower is about $600. If we figure that it will be good for only one job, that job must be large enough to warrant the expenditure of $600 to avoid using the ordinary wheelbarrow method. The difference in cost of placing concrete by the two methods is usually about 75 cts. per cu. yd. of concrete so that if we have a job containing more than 800 cu. yd., or say 1,000 cu. yd., the chuting system will be the more economical. If the tower is built carefully and so that it may again be erected on other work it will pay to build one for smaller jobs. It will cost about $200, however, to erect such a tower on any job, so that on a job containing less than 200 cu. yds. it would not be practicable to use a tower, especially a tower of such size.

There will be no difference in the cost of concreting as between wooden and steel towers, as their operation is practically the same. The difference in first cost is the main consideration and for towers 75 ft. high this is about $400. The wooden tower can not, however, be expected to maintain its rigidity for more than a half dozen jobs and there is no doubt that if a permanent tower is desired, a steel tower will be more economical than a wooden tower after five or six jobs have been built. This is very well illustrated by comparing the cost of setting up. Assuming that the cost of the erection of the wooden tower is $200 and the cost of erecting the steel tower is $100, we have added $800 to the original cost of the wooden tower by the time it has been erected for its fifth job. The money invested in it then is $600 + $800 or $1,400. By the time the steel tower is erected for its fifth job the money invested in it is $1,000 + $400 or $1,400, an equal amount to that invested in a wooden tower. The wooden tower may still be in fair condition but it is reasonable to believe that the steel tower will remain in good condition for a much longer time and it will cost only about half as much to erect. We may assume, therefore, that a portable wooden tower is economical for jobs above 1,000 cu. yds. and until it has been erected five times, and that a portable steel tower would be more economical if its use is contemplated for more than five jobs.

The first towers used for hoisting concrete were naturally of wood and were located entirely within an area to which chutes could be run in all directions. Later, auxiliary towers were used in connection with very high main towers to carry concrete to a considerable distance, this distance always being controlled by the angle of the chute (about 23° to 30°), and the height of the main tower. The steel tower was primarily substituted for the wood tower to provide a permanent "knock down" structure which

could be used over and over. Its rigidity as compared with the wooden tower has finally led to the portable feature. This feature makes the steel tower more economical than wooden towers as auxiliary towers and also makes the steel tower more economical

Fig. 88. View of Concreting Tower.

than a fixed wooden main tower under the conditions illustrated in Fig. 165, which pictures the construction of a thirty-stall concrete roundhouse for the Lake Shore & Michigan Southern Railway, and is described in *Engineering and Contracting*, August 2, 1912. Here, it was at first planned to build three wood towers

for the construction of this roundhouse, which is 405 ft. in diameter. These were estimated to cost at least $2,200, as against $1,000 for a single steel tower, which could be moved from place to place.

Other towers built for this purpose will no doubt be improved, as the experience with this one has shown to be advisable. A swivel post should be placed at the top to fasten the guys, so that the tower may be turned around more easily, and probably some sort of truck placed underneath would facilitate the shifting of the tower.

Figure 88 shows the construction of the tower which is 72 ft. high. The steel work is carried on wooden skids which lie across two railway rails forming a truck. On the bottoms of the skids, where they rest on the rails, are steel plate shoes which are fitted with clamp butts for anchoring the tower to the rails. The tower is also guyed, the guys running through blocks at the deadmen.

Referring to Fig. 88, it will be seen that attached to the tower is a main spout 60 ft. long consisting of a U-shaped trough 10 in. across at the top and 10 in. deep, made of galvanized sheet iron. This trough is open, except at its lower end, where it discharges into the 30-ft. swivel pipe leading to the forms. The concrete can be spouted 95 ft. with this arrangement of 110 ft. with an extension pipe, which is kept at hand. This trough is supported by a light steel truss, which is shown in the photograph. A special feature is the support of this spout and truss by a 40-ft. boom which is rigged from the top of the tower and held in place by a steel cable running to a winch placed at the foot of the tower. The construction of the trough on top of the truss is such that the wearing parts may be easily removed and replaced without disturbing the truss itself.

Comparative Cost of Wood and Steel Towers. The following notes appeared in *Engineering and Contracting*, Jan. 24, 1912. During the construction of a reinforced concrete building in Chicago the contractors used two hoisting towers, one of which was the ordinary wood tower and the other a steel tower made of light structural shapes. The towers were operated under the same conditions and the comparative cost of the towers for the work was in favor of the steel tower, although the whole cost of the tower was charged against the first job.

The cost of the tower given by the contractor follows:

Lumber	$175
Framing	50
Erecting	250
Dismantling	100
Total	$575

The cost of the steel tower was as follows:

Tower	$465
Erection	40
Dismantling	40
Total	$545

This is a saving of about 5% in favor of the steel tower on the first job. If the cost of the tower were charged off on the

Fig. 89. Steel and Wood Hoist Towers on Concrete Building Work.

first job, then on the second job the cost would evidently be only $80, or a saving of about 85%. This is probably a somewhat excessive estimate as some minor items would no doubt enter in,

but in the long run it is quite evident that the steel tower would be more economical than towers built of wood.

The steel tower is built in 12-ft. sections, is of structural shapes throughout and is supported by guys entirely independent of the building. This is an advantage because the tower can be constructed to full height before the building is erected. The weight of the tower is about 60 lb. per lineal foot, so that it is not necessary to dismantle the bottom section, which can be easily handled by three men and set up and leveled ready for the erection of the other sections. These can be erected piece by piece in place or the sections can be set up on the ground and hoisted to place by a derrick. Three men can erect three sections a day.

The tower is designed primarily as a hoist for an automatic dumping concrete bucket, and this bucket and a hopper is provided. The hopper can be set at various points on the tower for distributing the concrete by gravity.

A PORTABLE PLANT FOR MIXING AND CONVEYING CONCRETE FOR FOUNDATION WORK; LABOR COSTS OF 36,000 CU. YD. OF WORK.*

The accompanying photograph (Fig. 90) illustrates a portable concrete mixing and conveying plant which was used by the Great Lakes Dredge & Docks Co. on foundation work for a blast furnace plant near Chicago. The concrete plant is built on a platform 20 ft. square which is mounted on rollers. On the platform a 75 hp. horizontal boiler is mounted which furnishes steam for the operation of the Ransome mixer and Lidgerwood hoist. The 1-yd. mixer is placed near the rear of the platform and a hopper bin is erected above it, which has a capacity of 10 cu. yd. of stone and 5 cu. yd. of sand. The bins were filled from cars on a parallel track, by means of a locomotive crane and clamshell bucket. Storage is provided for 500 bags of cement on the platform at one side of the mixer. The material from the storage bins is dumped into a 1-yd. batch hopper. From the mixer the concrete is delivered to a Ransome tower bucket which is raised 75 ft. and delivered into the chute. The chute consists of a 12-in. galvanized pipe, supported by two 80-ft. booms. From the ends of the booms lines run to equidistant points on the chute thus supporting it uniformly and keeping it in a straight line. The booms are swung horizontally over the work by hand. The

* Data taken from a table appended to paper by Victor Windett, presented to Western Society of Engineers on June 7, 1911, published in *Engineering and Contracting* July 5, 1911.

lower 60 ft. of pipe is made in movable lengths of 8 ft. The plant itself is pulled along on its rollers by attaching a line to a deadman and taking it in on the hoist.

The concrete work consisted of foundations for power house and blast furnace buildings. The work was started in 1910 and continued through the winter and spring of 1911.

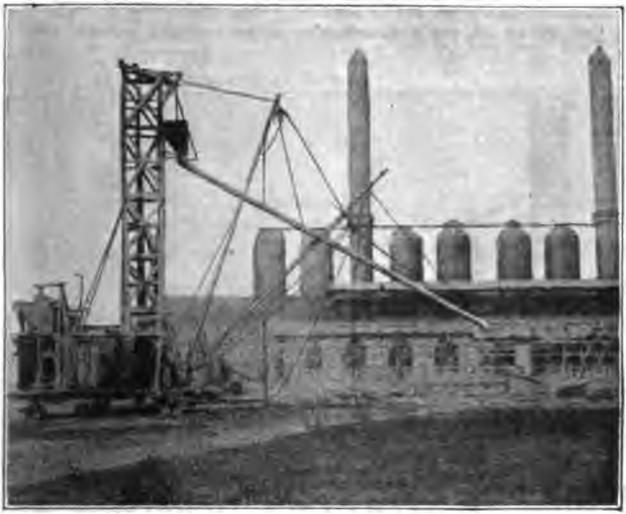


Fig. 90. View of Portable Mixer and Conveyor Used for Massive Foundation Work.

The work on the blast furnace building was massive concrete work, the blast furnace foundations consisting of concrete slabs 50 x 70 ft. square, and having a firebrick core averaging 23 ft. in diameter. There were 10,809 cu. yd. of concrete placed at a complete labor cost as given below:

Sq. ft. forms per cu. yd.	7.57
Sq. ft. footing surface (no forms)	8.54
Total days work	110
Actual concreting time, days	88
Labor days of 9 hours	5,020
Concrete placed per day of concreting days (yd.)	123
Concrete placed per day of total time (yd.)	98.5
Labor cost per cu. yd. per day per man	$ 0.46
Total cost per cu. yd.	$ 1.43

The work on the hot blast stove and boiler foundations was massive work, including 10,064 cu. yds. of concrete placed during the summer at the following cost:

Sq. ft. form surface, per cu. yd.		9.74
Sq. ft. surface without forms, per cu. yd.		16.1
Total days work		79
Total days concreting		57
Total labor days of 9 hours		3,977
Concrete per day of total time (yd)		128
Concrete placed per day of concreting time (yd.)		172
Cost per cu. yd. per man, per day	$	0.40
Total labor cost per yd.	$	1.24

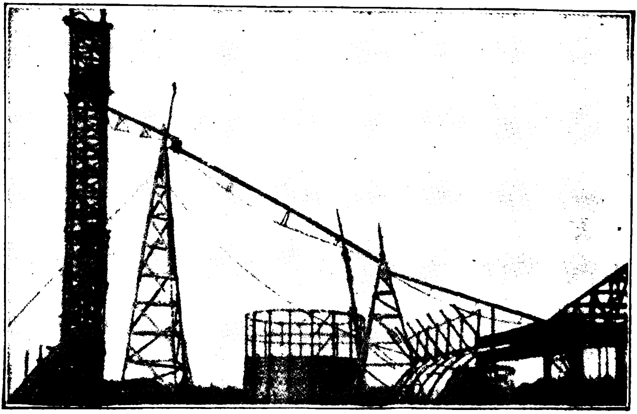


Fig. 91.

This work was done in the winter. The power house foundations consisting of light piers, floors and some massive piers, including in all some 3,733 cu. yd., were placed as follows:

Sq. ft. form surface per cu. yd.		12.8
Sq. ft. surface without forms, per cu. yd.		14.4
Total days work		75
Total days concreting		36
Total labor days of 9 hours		2,310
Yd. concrete per day of total time		49.6
Yd. concrete per day of concreting time		103.5
Cost per cu. yd. per man per day	$	0.62
Total cost per cu. yd.	$	2.02

The casting machine building foundations were built in the spring. These consisted of light piers and walls amounting in all to 1,225 cu. yd. This concrete contained no reinforcement.

Sq. ft. form surface per yd.		14.2
Sq. ft. surface without forms		....
Total days work		17
Total days concreting		14
Total labor days of 9 hours		922
Yd. concrete per day of total time		72
Yd. concrete per day of concreting time		87.5
Cost per cu. yd. per man per day	$	0.75
Total cost per cu. yd.	$	2.32

The work on the wharf consisted of 3,344 cu. yd. of concrete in massive work. Two rows of piles were capped with concrete forming a base for the walls supporting the rails of the unloading crane. This work was done in the winter and early spring. The data on the work are as follows:

Sq. ft. form surface per cu. yd.		6.1
Sq. ft. surface without forms, per cu. yd.		...
Total days worked		24
Total days concreting		20
Total labor days		1,290
Yd. of concrete per day of total time		139
Yd. of concrete per day of concreting time		167.5
Cost per yd. per day per man	$	0.39
Total cost per yd.	$	1.21

The construction of the piers for the steel trestle consisted of moderately heavy work amounting in all to 6,971 cu. yd of concrete. The work was done in the winter and the chuting system was not used. Instead the concrete was delivered in hand pushed Koppel cars of 1 cu. yd. capacity.

Sq. ft. form surface per cu. yd.		8.69
Sq. ft. surface without forms, per cu. yd.		14.7
Total days worked		70
Total days concreting		62
Total labor days		3,900
Yd. concrete per day of total time		100
Yd. of concrete per day of concreting time		113
Cost per yd. per day per man	$	0.56
Total cost per cu. yd.	$	1.74

The general averages and totals taken from the above data urnish the following:

Total yd. concrete placed		36,146
Sq. ft. forms per cu. yd.		9.0
Sq. ft. concrete surface without forms (per yd.)		13.0
Total days worked		375
Total days concreting		277
Total labor days of 9 hours		17,419
Yd. concrete placed per day of total time		96.5
Yd. concrete placed per day of concreting time		130
Cost per yd. per man per day	$	0.482
Total average cost per cu. yd.	$	1.49

Included in the above labor costs is the placing of 500,000 lb. of steel reinforcement, or about 14 lb. per cu. yd. of concrete,

and the labor for erecting and dismantling the plant for handling the concrete. The rate of wages paid averages $0.344 per man per hour including the entire force employed.

Gravity Concrete Plant Carried on a Barge. A gravity plant mounted on a 38 by 120 ft. barge consisting of a steel tower 104 ft. high, roller bucket of 34 cu. ft. capacity, hopper capacity 54 cu. ft, boom chute of 80 ft. and counterweight chute 50 ft. long was used in the construction of revetment on the banks of the Mississippi River. The plant is stated to have placed 182 squares of pavement on its first day of operation.

SECTION 26

CONCRETE SIDEWALK AND CURB FORMS

Adjustable steel sidewalk and curb forms are extensively used and where the amount of work is large, their extra cost is justified.

SIDE RAILS (RIGID)

10 ft. lengths

Height in inches	Approximate lb. per ft.	Price f. o. b. factory
4	2.5	$ 3.80
6	3.5	4.60
8	4.4	5.60
10	5.2	6.80
12	6 0	8.00
18	8.3	12.00
24	10.4	16.00

Rails shorter than 10 ft. used in "ending up" work are to be had in lèngths of from 2 to 8 ft.

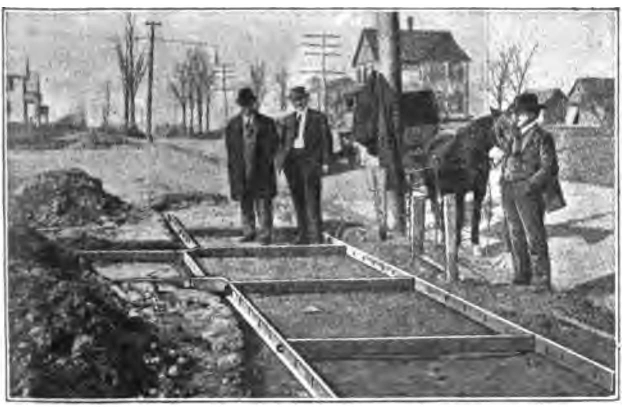


Fig. 92. Use of the 6-inch Radius Curve.

Flexible rails are to be had in the same lengths and heights as the side rails at about 50% higher prices.

Radius rails may be had in the same lengths and heights as the side rails at a price of about 100% higher for the smaller heights and 50% higher at the greater heights.

Flexible and radius rails are usually furnished in sets; that is, one for the inside and one for the outside curve. Separate inside or outside rails can be furnished when required.

Sidewalk Division Plates

Width of sidewalk	Cost of plates 4″ depth	5″ depth	6″ depth
3 feet	$0.90	$1.00	$1.10
4 feet	1.05	1.20	1.30
5 feet	1.20	1.45	1.60
6 feet	1.30	1.60	1.85

Fig. 93.

Combined Curb and Gutter Dividing Plates

Height of curb	Thickness of curb	Width of gutter	Cost
12″	5″	12″	$1.55
12″	6″	18″	1.80
12″	6″	24″	2.10
12″	6″	30″	2.35
12″	6″	36″	2.65

Curb Dividing Plates

Height of curb	Thickness of curb	Cost
12"	5"	$0.77
12"	6"	.77
16"	6"	.95
18"	6"	1.00
24"	6"	1.05

Steel Face Rails used with rigid side rails to form the front face of a gutter cost as follows:

4 in. high by 10 ft. long	$4.10
5 in. high by 10 ft. long	4.30
6 in. high by 10 ft. long	4.60
7 in. high by 10 ft. long	5.00
8 in. high by 10 ft. long	5.40

Steel Spacers used in curb construction for suspending the inside rail, and to space that rail the proper distance from the outside rail cost 28 cents each.

Battered Rigid Side Rails 10 ft. long cost $7.40 for the 10½-in. height and $8.10 for the 12½-in. height.

Beveled Edge Rigid Steel Side Rails 10 ft. long cost $8.30 for the 5-in. height and $8.70 for the 6-in. height.

Steel Sidewalk Radius Corners to attach to the rigid side rails $1.40 each for the 4, 5 and 6-in. height by 18 or 24-in. radius.

Steel Stakes cost as follows:

18 in. long	$0.18
24 in. long	.24
27 in. long	.26
30 in. long	.31
36 in. long	.36
42 in. long	.42

For longer stakes add 8 cents for each additional 3 in. of length.

Stake Clamps cost 14 cents each.

Steel Road Rails especially designed for use with concrete road finishing machines are furnished in all heights. The standard length is 10 ft. The prices f. o. b. factory are as follows:

4 in. high	$ 5.40
6 in. high	6.10
8 in. high	7.05
10 in. high	9.60
12 in. high	11.20

Steel Strike Off weighs approximately 8 lb. per ft. and costs as follows, f .o. b. factory.

14 ft. road	$24.00
16 ft. road	27.00
18 ft. road	30.00
20 ft. road	33.00

Steel Bulkheads for Concrete Roads, fitted with angles to facilitate handling, are priced as follows:

14 ft. road	$27.00
16 ft. road	31.50
18 ft. road	34.50
20 ft. road	38.50

These bulkheads may be had in any size and type at special prices.

Steel Division Plates for Concrete Roads, made of 3/8-in. steel plate to conform with the crown of the road are priced as follows:

14 ft. road	$20.00
16 ft. road	23.00
18 ft. road	2[illegible].00
20 ft. road	29.00

All the foregoing prices are f. o. b. factory.

Cement Workers Tools. The following are net prices at Chicago for tools used in constructing and finishing cement sidewalks. The prices are for iron nickel plated tools.

Jointer

2¾ in. wide, 6 in. long, each	$0.58

Narrow Jointer

1¾ in. wide, 8 in. long, ½ in. blade, each	$0.67
1¾ in. wide, 8 in. long, ¼ in. blade, each	.67

Straight End Jointer

3 in. wide, 6 in. long, ½ in. deep, each	$0.67

Narrow Straight End Jointer

1¾ in. wide, 8 in. long, ½ in. blade, each	$0.67
1¾ in. wide, 8 in. long, ¼ in. blade, each	.67

Driveway Groover

The following are net prices for driveway groovers, 3 in. wide and 9 in. long:

Groover, ¾ in. deep, each	$0.85
Groover, half round, each	.85

A 6-in. V-groover, ⅝ in. wide, ½ in. deep, costs 52 ct. each.

Straight End Groover

6-in. V-groover, ⅝ in. wide, ½ in. deep, each	$0.67

Edgers

The net prices of edgers, 3/8 in., 2¾ in. and 6 in. long, are as follows:

¾ in. turned edger, each	$0.58
¾ in. turned edger, 10 in. long, each	1.35

NARROW EDGER

8 in. long, 1¾ in. wide, each	$0.67
6 in. long, 1½ in. wide, with guide	.58

A reversible handle edger, right or left, 1 in. turned edge, ¾ in. radius, 3 in. wide and 6 in. long, costs 67 ct.

CIRCLE EDGERS

⅜ in. radius, each	$0.50
¾ in. radius, each	0.50

A square edger 3 in. wide, 6 in. long, both edges rounded, with 1½-in. cutting edge, costs 83 ct. Bevel edgers, 2¾ in. wide, 6 in. long, with either ⅜-in. bevel or ⅝-in. bevel, can be bought at 57 ct. each. Corner tools, one end straight, the other curving back, 6 in. long, 1½ in. wide, also cost 57 ct. each. Curbing edgers with 2 in. turned back with radius of 1½ in., 3½ in. wide, 6½ in. long, cost $1.20 each. Raised (tuck) pointers, 3/16, ¼, 5/16, ⅜ or ½-in. size, cost 50 ct. each.

Long handled finishing tools cost as follows:

Trowel with one long adjustable handle, one short handle, one wrench; price 15 in., $4.50; 24 in., $6.60. Jointer, with one long handle, one short handle, one wrench; price, $4.50. Edger, same equipment, $4.50. Six-ft. compasses, $3.85.

Long Handled Sidewalk Tools with patented double action device cost as follows:

Finishing trowel, 24 in. long, 5 in. wide	$7.50
Float, 24 in. long, 6 in. wide	7.50
Divided float, 16 in. long, 6 in. wide	7.50
Jointer, 16 in. long, 5 in. wide	7.00
Floor beader, 10 in. long, 3¼ in. wide	4.50
Edger, 10 in. long, 4½ in. wide	4.75

Long handled sidewalk marker, steel blade, 6 ft. handle, that will cut through 5 in. of concrete cost $1.25.
Cement tamps, 8 in. square with 4 ft. handle cost $1.50. 10 in. square, $2.
Dirt rammer, 5 in. dia., $1.50.
Steel grout cutter with forged steel blade 20 in. long, 4 in. wide, costs $6.
Sidewalk rollers with line patterns, 6 ft. handle, 7 to 12 in. long, iron, cost $3.75. Dot pattern, $4.25.
Steel mortar box having an ample capacity for ½ cu. yd. weighs approximately 200 lb. for shipment and is priced at $14 f. o. b. factory.

SECTION 27

CONVEYORS

Belt Conveyors were first used in 1868 and since that date have attained great popularity as a means of conveying all sorts of solid materials. The great advantages of belt conveyors are the small horsepower required to drive them, their noiseless operation and large capacity.

Power Required. In a concrete mixing plant in New York City a belt conveyor 24 inches wide, traveling at a speed of 400 feet

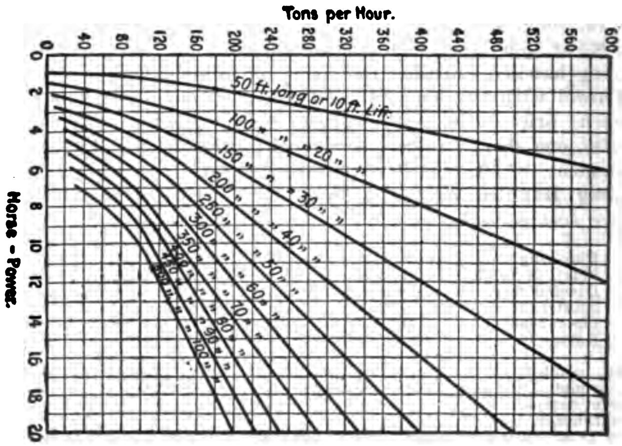


Fig. 94. Diagram Showing Power to Operate Belt Conveyors.

per minute, and carrying the concrete from the mixer to the forms, required but 1 horsepower to drive it. The belt which carried the materials to the mixer was 20 inches wide, 228 feet long and had a rise of 34 feet. It traveled at a speed of 350 feet per minute and required but 6 horsepower to drive it with its load of 100 tons per hour. In the Transvaal a belt with a

horizontal carry of 200 feet and a vertical lift of 48½ feet, conveying 71.4 tons per hour, required 8.1 horsepower to drive it. A belt with a horizontal carry of 500 feet and a vertical lift of 25½ feet required 8.6 horsepower to convey 90 tons per hour, and 2.9 horsepower to drive the unloaded belt.

The capacity of belt conveyors is shown in two diagrams (Figs. 94 and 95), published by Mr. R. W Dull in the *Chemical Engineer*, August, 1909. These are based on good feeding conditions and variations as great as 50% are likely. Some of the curves are stopped off at certain sized belts, as with large pieces

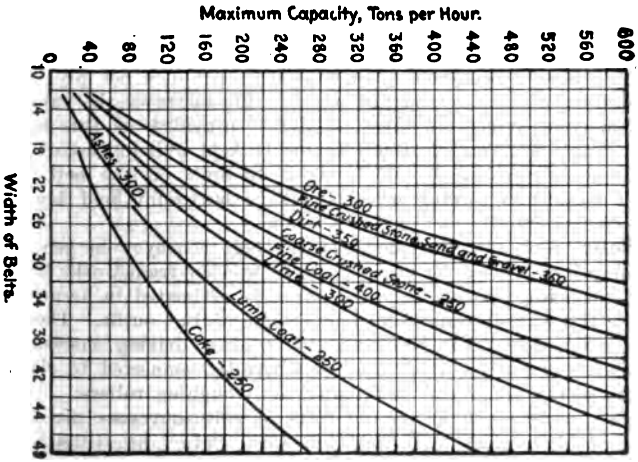


Fig. 95. Diagram Showing Capacity of Belt Conveyors.

it is not advisable to use a conveyor any narrower, regardless of what capacity is required. It is advantageous to install a feeding device of some kind if the feed is irregular. Materials should be delivered to the belt in the direction of motion of the belt and with as near the same velocity as possible.

Wear. Small belts of stitched canvas or woven cotton are often used and are usually well oiled. For large, permanent conveyors, rubber belts composed on a cotton duck foundation are most satisfactory. Mr. George Frederick Zimmer in *Cassier's Magazine* for August, 1909, gives the following table showing the wear on different materials subjected to a uniform sand blast for 45 minutes:

Rubber belt	1.0
Rolled steel	1.5
Cast iron	3.5
Balata belt, including gum cover	5.0
Woven cotton belt, high grade	6.5
Stitched duck, high grade	8.0
Woven cotton belt, low grade	9.0

The rubber covering performs two offices, that of resisting wear and that of preventing moisture from reaching the body of the belt.

The Number of Plies Necessary is given by Mr. C. K. Baldwin. Belts 12 to 14 inches wide, not less than 3-ply; 16 to 20 inches wide, not less than 4-ply; 22 to 28 inches, not less than 5-ply, and 30 to 36 inches, not less than 6-ply. The tension on a belt must not be more than 20 to 25 lb. per inch per ply and a good belt should have a breaking strain of 400 lb. per inch per ply.

Belts are usually troughed because this increases the capacity. A sufficient number of idlers should be provided, as this lessens the chance of damage. Idlers should be kept well lubricated with a viscous lubricant as oil is liable to spill on the belt. The best method of joining belts is with a butt-joint held together by clamps.

Costs. For contract purposes the belt conveyor is generally mounted on a more or less elaborate wooden framework, housed or otherwise, the cost of which must be estimated in accordance with the special conditions and design of the outfit. The belt conveying apparatus proper consists of a driving mechanism, which is often belted or sometimes directly connected to electric motors; the idlers and belts; and the troughing rollers.

The following notes on the costs of belt conveyors are taken from "Mechanical and Electrical Cost Data," by Gillette and Dana.

In taking up the cost of belt conveyors, the questions of deterioration and amortization must be duly considered. In the handling of certain materials, lighter and cheaper belts — and the belt is the most expensive item entering into the equipment of a belt conveyor — may sometimes be recommended than that required for more severe service; but ordinarily the best grade of belt is none too good, no matter what service it may be subjected to. The large capacity of the equipment makes the question of initial cost of secondary importance. The general formula given in Fig. 96 and the costs graphically depicted thereon are those for the average high grade belt conveyor with suitable rubber belting and well designed grease lubricated idlers. The cost of the belt is included in the first term of the second member of the formula, so

that the cost of the conveyor with a cheaper belt is readily obtainable from the same formula simply by reducing the coefficient of the length by the difference of the cost of two ft. of high grade rubber belting with that of two ft. of the cheaper belt. Conveyors equipped with ball bearing idler, etc., cost about 5% more than the figures indicated by Fig. 96, but this difference in cost is frequently offset on shipments to distant points by the decrease in freight rates, ball bearing idlers weighing less than grease or oil lubricated idlers.

An arbitrary charge which covers most simple installations of belt conveyors of ordinary length is about 1.5 cents per hour per inch width of conveyor for installations with grease lubricated idlers, or a charge of 1 ct. per in. width for conveyors equipped with ball-bearing idlers.

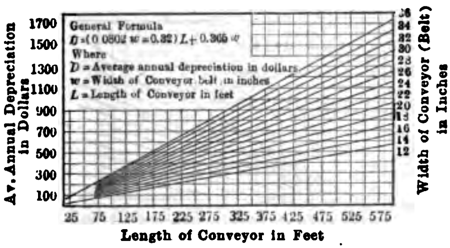


Fig. 96. Average Cost of Standard Troughed Rubber Belt Conveyors with Grease Lubrication.

The expense entailed for grease or oil and the other incidental supplies required to keep the equipment in good operating conditions is, in a conveyor in frequent use, very nearly directly proportional to the hp. consumed in operating the conveyor, and averages about 0.625 ct. per hr. per hp. Of this charge about 0.5 ct. per hr. is the cost of the grease required, so that the average supplies charge for roller-bearing conveyors is but about 0.125 ct. per hr. per hp. consumed.

Deterioration and amortization of belt conveyors constitute an exceedingly complicated subject and one that here must, perforce, be treated in a very general manner. Depreciation is due not only to wear but to constant and quite apparent continuous deterioration of the belts, whether they are in use or not, so that the depreciation charge is little affected by careful use, provided, of course, that the equipment is operated a reasonable amount of the time. This deterioration is largely due to the hardening of the rubber cover and the loss of resiliency, and is more apt to be ac-

centuated by idleness than by sane and careful use. The rest of the mechanism is not more greatly affected than other mechanical equipment, if well cared for and not abused. Ordinarily a depreciation charge of about 25% on the belt and about 10% on the balance of the equipment covers all reasonable wear and tear: the general formula on Fig. 97 is based on such apportionment. The curves shown are plotted from data compiled in a more intricate and exacting manner, but the discrepancy between the results obtained from the general formula and the readings derived from the chart is so slight that dependence may be placed on either the figure readings or the formula. For conveyors with roller-bearing idlers the depreciation charge is reduced about 10%.

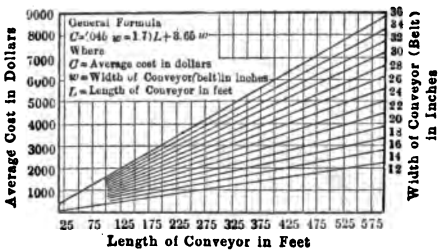


Fig. 97. Annual Depreciation of Standard Belt Conveyors.

Belt conveyor installations are, of course, subject to the usual burden of fixed charges, consisting of interest on investment, insurance, and taxes. These ordinarily amount to about 8.5% of the initial cost per year (6% interest, 1% insurance and 2% of three quarters of the value of the property for taxes).

Note. At speed of 300 ft. per minute a 12-in. belt should not carry material more than ½-in. in diameter; 8-in. belt, material not more than 1½-in. in diameter; 24-in. belt, not larger than 3-in.; 30-in. belt, not larger than 4-in.; 36-in. belt, not larger than 6-in. in diameter.

When speeds up to 600 ft. per minute are used material larger than 2-in. size is not likely to stay upon the large belts and for material 1-in. and larger a belt no smaller than 18-in. should be used.

Economic Speeds of Conveyors for Various Materials. The following tables appeared in *Industrial Management*, Nov., 1916, in an article by Mr. R. Trautschold.

ECONOMIC SPEEDS OF BELT CONVEYORS FOR VARIOUS MATERIALS

Material	Average weight in lb. per cu. ft.	Speed in ft. per min.
Coke	33.5	250
Broken stone (coarse)	165	275
Lump coal	55	275
Ashes	45	300
Lime and cement	65	300
Ore (average)	125	350
Crushed stone	160	375
Sand and gravel	110	375
Fine coal	50	400

ECONOMIC SPEEDS FOR BUCKET CONVEYORS FOR VARIOUS MATERIALS

Material	Advisable speed in ft. per min.
Coke	40
Broken stone (coarse)	50
Lump coal, run of mine	50
Ashes	60
Lime and cement	60
Ore (average)	70
Crushed stone	70
Sand and gravel	70
Fine coal	80

The following notes on belt conveyors for concreting material appeared in *Engineering News*, Nov. 26, 1914.

Belt conveyors have been installed at Randall's and Ward's Islands, New York City, for handling concrete material from scows to storage piles, in the construction of the Hell Gate Bridge, crossing the East River. The belt at Ward's Island is 380 ft. long by 24 in. wide and inclined at 21°. At Randall's Island a 20-in. belt is used.

The receiving dock for materials at Ward's Island is double-decked. The loose materials are unloaded from the scow into a common hopper on the upper deck of the dock, by a derrick equipped with a grab bucket, located on the dock. The belt is fed by a chute from the hopper. The bags of cement are lifted from the scow in 9-bag slings, by means of a gasoline hoist on the scow. Four men, working two and two, unfasten the slings and place the individual bags on the belt. As many as 1500 bags per hour have been handled in this manner without confusion.

The sand and stone or gravel are lifted by the belt, above storage piles, where they are dropped by a tripper. From the piles they are later rehandled into cars for distributing to different parts of the work. Coal for the dinkey engines is conveyed by the belt in the same manner. The bags of cement are discharged from the belt on a table in a storage house, where they are piled.

The number of men employed on this work at Ward's Island is as follows: A gasoline-hoist operator on the scow; a man to direct the sling; three to make up the slings; four to place the bags on the belt; one to operate the tripper, and 12 to 15 men in the cement-storage room.

At Randall's Island the scheme of handling is essentially the same, but instead of having a separate hoist for the cement, the

Fig. 98. Belt Conveyor at Hell Gate Bridge for Handling Cement, Sand and Stone.

one derrick on the dock unloads all materials. To handle cement out of the scow, the grab bucket is lowered into the scow and about 12 bags placed in it and lifted to the dock. At this plant, also, a second belt, 18 in. wide, runs from the storage piles to the concrete mixer.

Mr. Edwin H. Messiter says that for ordinary mine run ore the largest lumps of which do not contain over 1 cubic foot, a 30-in. conveyor is suitable. Sizes of lumps which may be carried by the several sizes of conveyors are:

Lumps	Conveyor	* Tons per hour
12 in.	30 in.	560
8 in.	24 in.	360
6 in.	20 in.	250
4 in.	16 in.	160
3 in.	14 in.	120
2 in.	12 in.	80

* Last column is capacity for ore weighing 100 lb. per cu. ft. at a speed f 400 ft. per minute.

Speeds up to 400 ft. per minute may be used and 700 ft. in pecial cases.

Inclination should be limited to 20° from horizontal, but 26° nay be used with steady feed and fine material. Life of belts aries with tonnage. If correctly designed and made of proper naterials on large conveyors, belt renewals will approximate 0.1c. er ton of ore. Cost is greater on small conveyors than on large nes. Horsepower required will average about 0.00015 horsepower per ton per foot of horizontal distance carried, plus 0.001 orsepower ton per foot of height elevated.

Fig. 99. Movable Tripper.

Belt conveyor equipment of one make costs as follows:

Automatic Tripper. These trippers are designed to distribute naterial carried by belt conveyors on long piles or large bins. They travel on a track between two points, automatically reversing and discharging their loads continuously. They can be o regulated as to discharge at one point. The following gives he approximate prices of these trippers without chutes:

Width of belt inches	Price	Width of belt inches	Price
12	$675	30	$ 980
18	825	36	1,045
24	900		

Hand Propelled Trippers discharge materials at fixed points to which they are moved along a track by hand. They cost as follows without chute:

Width of belt inches	Price
12	$325
18	795
24	500

Troughing Idlers and return idlers with side clamp boxes for wood stringers cost about as follows:

Width of belt inches	Troughing idlers	Return idlers
12	$ 5.85	$ 4.20
18	7.15	5.05
24	10.85	8.70
30	12.00	9.50
36	14.65	11.00

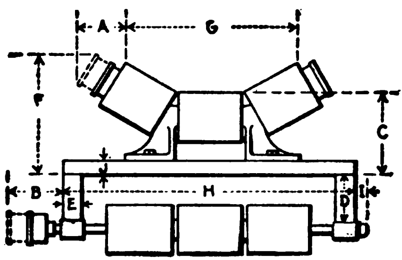


Fig. 100. Troughing and Return Idlers.

Flight Conveyors. The following is taken from "Mechanical and Electrical Cost Data." When great quantities of material which is not liable to damage by direct contact with the propelling flights have to be handled at a rapid rate in a limited space, when the cost of power is not a governing condition and the initial investment is a serious consideration, flight conveyors are frequently resorted to. Their capacity is great owing to the compact load per foot, notwithstanding the comparatively low speeds at which they have to be run.

As in the case of belt conveyors, the economic speeds for various materials vary considerably, and the economic value of a flight conveyor depends upon its operation at the highest speed suitable for the load. Good practice is listed in Table II.

TABLE II

Material	Advisable speed in ft. per min.
Coke	100
Broken stone (coarse)	125
Lump coal (run of mine)	125
Ashes	150
Lime and cement	150
Ore (average)	175
Crushed stone	175
Sand and gravel	175
Fine coal	200

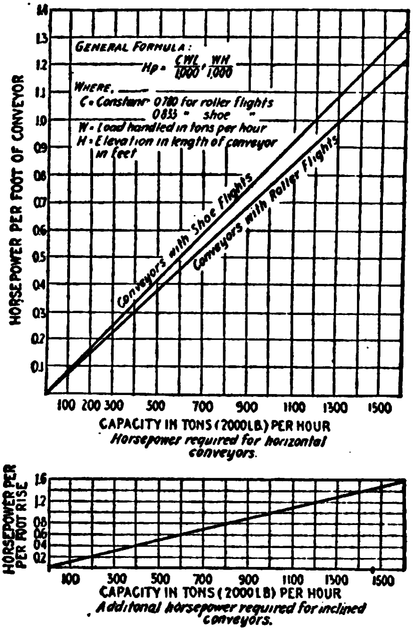


Fig. 101. Horsepower Requirements of Flight Conveyors.

A general formula for calculating the power requirements of flight conveyors with double strands of chain, the usual type found in the manufacturing plant, and a graphic presentation of calculated results are given in Fig. 101. The reduction in power consumption carried by equipping the flights with rollers or wheels is not as great as is generally claimed, for the main consumption of power in any flight conveyor is in dragging along

the load, the power consumed in dragging forward the chains and flights being appreciably secondary. Sliding-shoe flight conveyors, when fully loaded, consume but about 10% more power than similar flight conveyors in which the flights are mounted on rollers. Equipping the flights with rollers adds to their cost to some extent, but reduces the rate of depreciation, and is in reality an economic gain.

The depreciation of flight conveyors is naturally rapid, for the load exerts a very destructive scouring or abrasion on both the flights and the trough. This deterioration is naturally much more pronounced when handling certain materials than it is when less destructive materials are dragged through the trough. The deterioration due to the handling of certain materials is so very much more marked, in fact, that the character of the load must be taken into consideration in any reliable investigation of the

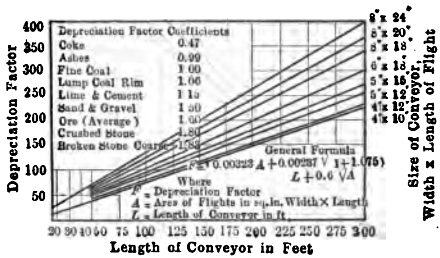


Fig. 102. Depreciation Factors for Standard Flight Conveyors.

average depreciation charge. Arbitrarily assuming a convenient basis of comparison, an average depreciation factor is arrived at in the general formula on Fig. 102, which, when multiplied by the "depreciation factor coefficient" given on the same chart, gives the average annual depreciation in dollars. The depreciation amounts to about the same in similar conveyors whether they are equipped with sliding-shoe flights or with roller flights, although the rate of depreciation is slightly less for the more efficient type.

Flight conveyors are usually shorter than belt conveyors, and in addition they require more attention in the way of opening gates, etc., so that the labor charge per ft. of conveyor is higher than in the case of belt conveyors, and averages between 2 and 3 ct. per in. width of conveyor. It is not correspondingly higher per tonnage handled, however, because of the large capacity of a flight conveyor of the same width and length of flight.

The charge for incidental supplies, as in the case of belt con-

veyors, is almost directly proportional to the power requirements; and as a number of incidental repairs can logically be charged to the same expense, safe figures for this item are 2 ct. per hr. per hp. for conveyors with sliding-shoe flights and about 10% less, or 1.8 ct. per hr. per hp. consumed, for conveyors in which the flights are furnished with rollers. The incidental repairs on the latter type of conveyor, chargeable to the item of "supplies," are less costly than those on flights with sliding shoes, but the lubrication charge is higher, so that the saving of the more efficient construction is only about 10%.

The burden of interest on investment, insurance, and taxes is proportionally no higher than in the case of other conveying equipment and on the average amounts to about 8½% per year of the initial cost of the installation, in addition to which there is usually an annual renewal charge of about 20%, which is in excess of the depreciation usual to other conveyors.

Belt Elevator. The life of belts of the same grade varies widely between limits according to tonnage carried, the length of belts, and the economic layout of the whole arrangement. On large belts of course the cost for repairs per unit of material delivered will be considerably smaller than on small belts. For special work, such as crusher plants and outfits of similar kind, the operation is almost automatic and with the exception of renewals which can be made rapidly there is practically no interruption to continuous service.

At the Union Stock Yards in Chicago a belt carrier with 24-in. x 24 in. buckets and a vertical lift of 58 feet with a 38-ft. horizontal run had been in operation about five years handling an average of 2,500 tons of coal per week, with no cost for repairs, and in 1908 was not likely to need repairs for another five years.

In Pittston, Pa., operating on a 25° incline and conveying coal 355 feet with 48-in. wide buckets, a belt carrier installed in 1902 handled 130,000 tons a month and after four years was in excellent condition. Cost of repairs averaged: material, .04c per ton handled; labor, .06c per ton handled, these repairs being the renewal of the carrier rollers and the driving pinion of the head gear.

The illustration (Fig. 103) shows a twenty-four inch conveyor one hundred feet long supplied Charles F. McCabe of the Robins Conveying Belt Co., for removing 10,000 cubic yards of earth and rock at 181st street and Jerome avenue, New York. The picture shows the very disadvantageous circumstances under which such a belt conveyor will work to advantage. Earth was shoveled on to the conveyor by hand and was discharged from the head end to wagons. Pieces larger than a man's head

were frequently placed on the conveyor, and were carried successfully, although it ran at times at an upward inclination of over 23 degrees. A Mundy engine, located in a pit beneath the tail end, drove the conveyor.

In the installation illustrated and described in the foregoing it was impossible to support the conveyor by any other than the most crude supports. This fact, however, did not interfere with the successful operation of the conveyor, nor did it injure the machinery to any appreciable extent. The belt itself, when the work was completed, showed little signs of wear.

Fig. 103.

Figure 104 shows a Robins Belt Conveyor used by Ryan & Parker in excavating for the foundation of the power house of the New York Gas and Electric Light, Heat and Power Co. The earth was delivered to the conveyor from wheel scrapers through bridges, and the excavating was done by practically the same means, employed more recently by F. M. Stillman & Co., for their work at East 12th street, New York. The conveyor was driven at its head end by a small horizontal engine, very little power being required. It was subjected to the roughest kind of usage; rocks weighing over 100 pounds were constantly dumped upon it, but never caused a moment's stoppage during the entire work. The width of the belt was 30 inches, and the actual quantity removed exceeded 1,200 cubic yards per day. The

work was all done during very cold weather, in December and January.

A Steel Incline and Tipple is often used to convey earth from a steam shovel to the top of a high bank where it is dumped. Such a machine is illustrated in Figs. 105, 106. The steel truss of the incline weighs 8,500 lb., and the total load of boilers, without cars, etc., is 100 tons. The engines are 11-in. x 18-in., double

Fig. 104.

cylinders, and their cost with the boiler was $2,700. The shovel cut was 20 ft. wide, 18 ft. deep and the best month's record was 920 cubic yards per 10-hour shift. The whole machine cost about $4,000, prior to 1912.

Estimated Cost of Unloading and Storing Coal with V Bucket Elevator Conveyor. The following notes by Mr. G. P. Carver appeared in the *American Wool and Cotton Reporter*, May 20, 1920:

Unloading a car of coal by hand requires about twenty hours

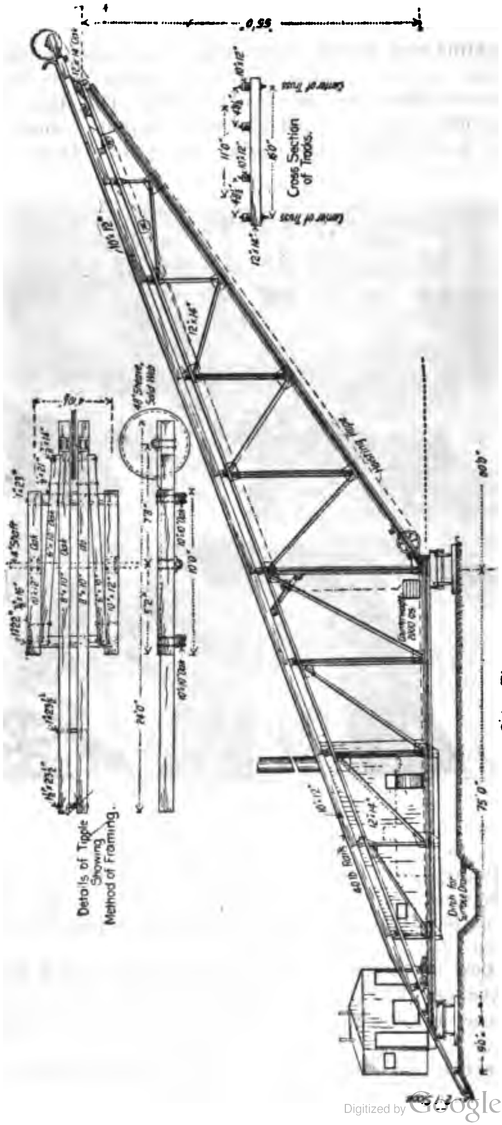


Fig. 105. Side Elevation of Steel Tipple.

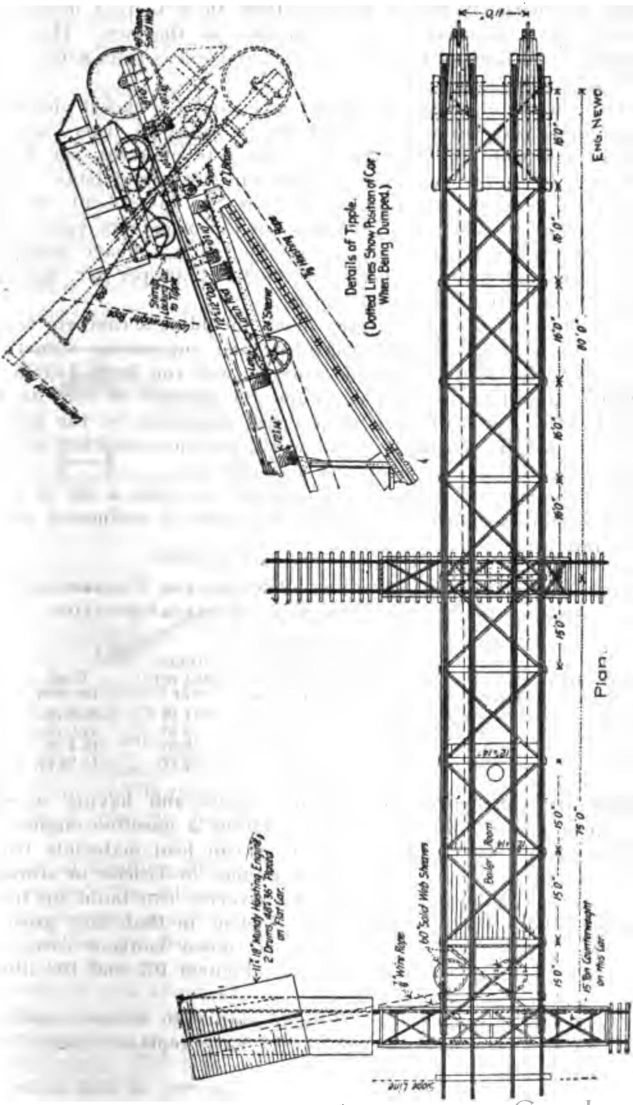


Fig. 106. Ground Plan of Steel Tipple.

labor, and with six men it requires from three to four hours, or possibly more, depending on the efficiency of the men. The cost to unload and trim coal back from cars by hand is from $20 to $30 per car.

With the use of a concrete track hopper and a V-bucket elevator, with supporting frame-work, coal can be unloaded from cars by one, or not more than two men at the rate of a car per hour, and at a cost of about $3.00 per car for power and labor. The cost per car chargeable to interest on the investment in the unloading plant and for depreciation in the machinery runs from $4.00 to $8.00 per car, according to the yearly tonnage handled, making a total cost to unload of $7 00 to $11.00 per car, against $20.00 to $30.00 for hand unloading.

The total cost of a discharging plant, including a concrete track hopper, a V-bucket elevator-conveyor, and supporting structure for same, with chute to ground storage, will run from $4,000 to $10,000, according to its height and the amount of coal to be stored. The cost will also be governed somewhat by the conditions at the site of the proposed work, such as condition of the ground, availability of labor and material, etc.

As a comparison of the cost to unload and store a car of coal under certain conditions the following table of estimated costs is of interest:

TABLE GIVING COST PER TON AND PER CAR FOR UNLOADING AND STORING COAL WITH V-BUCKET ELEVATOR-CONVEYOR

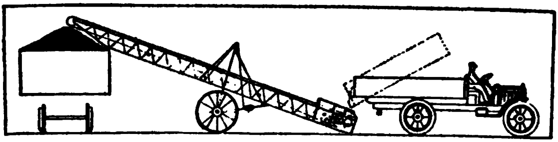
Number of cars received per year	Cost of installation	Cost of labor and and power per car	Plant interest and depreciation per car	Total cost per car	Cost per ton
50	$4000	$3.00	$8.40	$11.40	22.8 ct.
100	5000	3.00	6.50	9 50	19.0 ct.
150	6000	3.00	5.20	8.20	16.4 ct.
200	7500	3.00	4.87	7.87	15.74 ct.

Portable Conveyors, mounted on wheels and having a self contained power unit which may be either a gasoline engine or electric motor, have many uses. They can load materials from storage piles into wagons, or from wagons or trucks to storage piles, or in combination with fixed conveyors can build up high storage piles. These machines are efficient in that they greatly decrease hand shoveling and also cut down haulage costs by reducing the loading time for trucks. Figures 107 and 108 illustrate two of the uses of portable conveyors.

These conveyors have proved their ability to reduce handling costs from 50 to 90%. Single units have replaced from 3 to 20 men.

In the service of the Western United Gas & Electric Co. at its plant in Joliet, Ill., two B-G portable belt conveyors are operated in series in loading coke into railway cars. These cars are loaded in from two to four hours, according to size and type, with less than half the labor that was previously required to load them in from 7 to 10 hours. The saving in cost is about 50%. This is typical of results secured by use of conveyors in many places.

For elevating at angles under 25° a plain belt is employed. For angles of 30° to 35° a belt equipped with steel flights is provided to prevent the material slipping down the grade For chemicals that will corrode metal conveyors of similar design are provided with wooden frames.



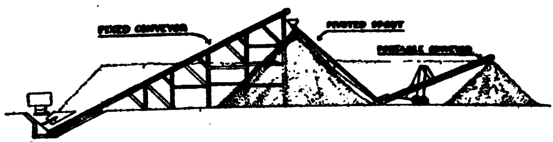


Fig. 107. Sketch Showing How Conveyor Is Used to Load a Railroad Car from a Motor Truck — the Truck Dumping Directly into the Hopper End of the Conveyor.

Fig. 108. Sketch Showing the Use of Permanent Conveyor, a Chute and Portable Conveyor for Building Storage Piles Well Back from the Railroad Track.

Cost of Loading Bricks into a Box Car Using a Portable Belt Conveyor. The following observations are by Mr. A. C. Haskell in *Engineering and Contracting*, Sept. 15, 1915. The box car was on a siding and the bricks were: (a) in piles about 30 ft. away and (b) brought in on small flat cars on an industrial track parallel to and about 40 ft. from the siding.

The conveyor was mounted on two wheels of about 4 ft. diameter, and was driven by a small motor supported on the frame work. The belt was 20 in. wide, 20 ft. long and had a speed of 240 ft. per min. The lower end was 1.5 ft above the

ground and the upper end about 2 ft. above the car floor and extending about a foot within the car.

One man stood at the foot of the conveyor and received bricks, four at a time, passed to him by two others alternately from the piles and placed them on the conveyor. Two men standing at either side of the belt in the car, took them off and passed them alternately to two others, at either side, who piled them in the car. The following time study was made when loading from the piles:

100	bricks were loaded	in	1.07	min.
102	bricks were loaded	in	1.13	min.
103	bricks were loaded	in	1.17	min.
100	bricks were loaded	in	1.30	min.
405	bricks were loaded	in	4.67	min.

On this basis in an 8 hr. day 41,600 bricks would be loaded, which is between 3 and 4 carloads. Allowing 45 min. for shifting the conveyor, etc., the total would be reduced to 37,700.

9 men at $1.75	$15.75
1 foreman at $3.50	3.50
Conveyor at $0.50	.50
	$19.75

or $\$19.75 \div 37.7 = 52.4$ ct. per thousand.

Therefore to load a car with 12,000 bricks which is about the average would cost $6.30.

A time study was made when they were unloading the bricks from the flat Koppel cars with wheelbarrows and transporting them to the conveyor. The average number of men loading was two, and the average number of bricks per wheelbarrow was 73. The distance of travel to the foot of the conveyor was 30 ft. The average time to deliver the load of each wheelbarrow was 2.57 min. On this basis the total number of bricks handled per day by the three wheelbarrows would be:

$$\frac{480}{2.57} \times 3 \times 73 = 40,900$$

Allowing, as before, the time to shift, the number would be 37,000

2 men loading at $1.75	$ 3.50
3 men transporting at $1.75	5.25
9 men at conveyor at $1.75	15.75
1 foreman at $3.50	3.50
Conveyor at $0.50	.50
	$28.50

or $28.50 ÷ 37 = 72.2 ct. per thousand, or at the rate of $9.25 per carload.

Cost of Scoop Conveyors. The following table gives the cost of scoop conveyors. These conveyors may be had with either a low cleat belt or a high flight belt. The low cleat belt is used for conveying boxes, tile, brick, stone, sand, gravel, etc., and the high flight is intended only to handle coarse gravel and large lump coal.

Size of machine width of belt	length	Approximate shipping weight in lb.	Price f. o. b. factory
12 in.	14 ft.	800	$ 435
16 in.	14 ft.	900	525
12 in.	20 ft.	1100	535
16 in.	20 ft.	1250	625
12 in.	24 ft.	1400	660
16 in.	24 ft.	1600	750

The above prices are for conveyors with power unit included. This power unit may be either a gasoline engine or electric motor.

SECTION 28

CRUSHERS

Machines for crushing rock, ore and similar hard materials are in two usual forms. Jaw crushers and gyratory crushers. Jaw crushers are usually of smaller capacity than are gyratory crushers. The jaw crusher operates in general in the following manner:

An eccentric shaft in revolving imparts a backward and forward movement to a lever arm whose fulcrum is at the outside

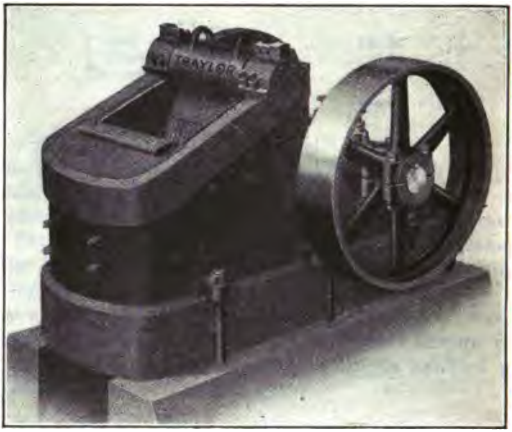


Fig. 109. Jaw Crusher

end. At a point between the power end of this arm and the fulcrum is a " toggle " to which is imparted a forward and backward movement by the arm and which in turn imparts the same movement to the lower end of a corrugated steel or cast iron crushing plate free at its lower and hinged at its upper end. Opposite this plate is a somewhat smaller fixed plate and the two together form the " jaws." By changing the toggle for a

larger or smaller, the "set" or size of the opening at the bottom of the jaws is regulated, and thereby the size of the product. The "jaw opening" is the width by the length of the opening between the upper ends of the crushing plates and determines the greatest size of stone that can be introduced.

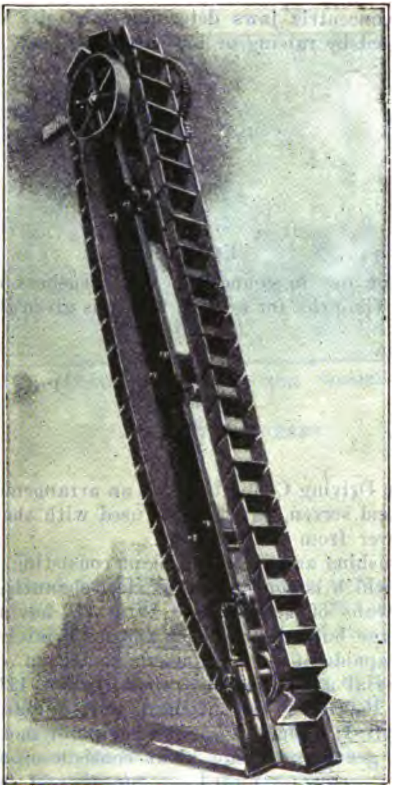


Fig. 110. Geared Elevator.

The jaw crusher is of limited capacity, its product is not uniform, and the machine itself is subject to frequent breakages due to the severe shocks it has to sustain. For these reasons the gyratory crusher was invented and is used wherever a uni-

form product of great quantity is essential. The principal objection to it is its non-portability. In this type of crusher a perpendicular shaft, to which are fastened the inner crushing plates revolves with an eccentric motion, inside of the stationary outer crushing plates. The actions of the inner jaw plates are both rolling and crushing The horizontal distance apart of the lower ends of the concentric jaws determines the size of the product and is regulated by raising or lowering the inner jaw.

Jaw Crushers

Capacity, tons per hour	Approximate weight in lb.	Price f. o. b. factory
3–4½	3,700	$ 725
8–12	6,000	980
12–22	12,000	1,800
24–42	23,000	3,120

Elevators

Elevators for use in connection with crushers are illustrated by Fig. 110. The price for a 14 ft. length is given in the following table.

Width of bucket in in.	Price	
	14 ft. length	extra per ft.
11	$200	$12
14	250	14
18	325	16

"Back Gear Driving Connection" is an arrangement for driving the elevator and screen, particularly used with the smaller sizes. and takes power from the breaker.

A gravel crushing and screening plant consisting of an elevator. the frame of which is constructed of steel channels, attached to a crusher by means of heavy angle bars and having an elevator with extra large buckets to convey the material from the pit to the crusher, capable of turning out about 150 yd. of crushed and screened material a day is illustrated by Fig. 111. This outfit weighs about 20,000 lb. without the power unit and costs $3,200 f. o. b. factory. It is operated by an engine or motor of 30 hp.

A portable gravel screening plant consists of a portable bin with revolving screen mounted on top thereof, an elevator of proper length attached to and forming a part of the outfit and a hopper placed in the ground under the elevator into which the gravel to be screened is put. The bin has a capacity of 20 tons and is driven by a 7 hp. gasoline engine placed under the bin. It weighs approximately 11,000 lb. and costs $1,600 f. o. b. factory without the engine.

A self-contained portable rig consists of the following:

Wheels, axles, truck frame and bin gates	$ 325
Bin and supports	175
Elevator with driving mechanism and chute screen	130
Crusher, 7 by 12 in.	800
Gasoline engine, 12 hp. complete	745
Complete rig with chute screen	2,175
Complete rig with rotary screen	2,325

Fig. 111. Portable Crushing and Screening Plant.

GYRATORY CRUSHERS

Capacity in tons per hr.	Approximate weight in lb.	Price f. o. b. factory
6–12	10.000	$1,400
10–25	14,000	1,750
20–48	22.000	2,600

Power required for the above crushers is from 6–10 hp. for the 6–12 ton size, 10 to 15 hp. for the 10–25 ton size, and 12 to 20 hp. for the 20–48 ton size. This type of crusher is illustrated by Fig. 112.

A reduction crusher or secondary crusher of the gyratory type which will take the tailings of a primary crusher up to 4½-in. cubes with a minimum discharge opening of ½-in. weighs about 14,000 lb. and costs $2,450 f. o. b. factory. This machine requires about 20 hp. to operate it. The approximate hourly capacity with a ½-in. opening is from 10 to 12 tons, and with a 1-in. opening is from 16 to 22 tons per hr.

The cost of moving a 9 x 15 crusher plant with non-portable bin a few miles and setting up ready for crushing is about $125 under average conditions.

Repairs. In crushing 224,203 tons of rock in 1886–7 an aver-

age of eight sets of crusher apparatus being in operation, the following new parts were required.

12 levers	@ $25.00	$300.00
9 jaw plates	@ 15.50	139.50
12 jaw plates	@ 12.00	144.00
Toggles, check plates and sundries		247.80
Total		$831.30

Fig. 112. Gyratory Crusher.

or an average of about $100 per crusher. This does not include babbiting the bearing or labor of making repairs.

Repairs for Rolls.

7 pairs tires	@ $120	$ 840.00
Gear wheels and pinions		335.00
Total		$1,175.00

or about $147 for each pair of rolls. The tires of the rolls used for coarse crushing are not turned when worn, but are replaced by new ones. For the screens 21 sets of perforated plates @ $60.75 = $1,275.75 were required, or an average of 2.6 sets per year per screen. The average life of the wearing parts of a jaw crusher is therefore about eight months; a set of screen plates about four months.

In Camp's "Notes on Track" there is a description of a crushing plant installed by the Pennsylvania railroad for the crushing

of track ballast. It consisted of a gyratory crusher of 40 to 50 cubic yards per hour capacity and a smaller auxiliary crusher. The stone from a large crusher was taken by a belt conveyor to a revolving plate screen 12 feet long by 4½ feet in diameter, divided into three sections having one-inch, two-inch, three-inch holes. On the outside of the one-inch hole screen was an auxiliary screen of ½-inch mesh. The rejected material was led through a chute to the smaller crusher whence it was again conveyed to the screens. After the stone had been screened it dropped into four bins. The products of the stone were 17% screenings, 8% ¾-inch stone, 33% 1½-inch stone, 42% 2½-inch stone. From the bins the material was chuted directly into cars. This plant was operated by a 150-horsepower engine. The labor necessary consisted of one fireman, one oiler and four laborers whose total wages per hour were $1.19½. The repairs and renewal of broken parts cost $500 for four hundred working hours. The above prices are prior to 1912.

The Dolese & Shepard Company of Chicago have estimated the life of their new 1912 stone crushing plant at twenty years with 5% annual depreciation. They have found from experience that repairs to crushers cost 5% annually, repairs to screens and conveyors 15%. The large size stone wears the screens and conveyors much more rapidly than the small size stone. For example, the screen for No. 9 crushers had to be renewed in nine months, whereas the other screens had been in service eight months and showed no wear.

The Illinois Stone Company, at Lemont, Ill., had in 1912 a stone-crushing plant with a capacity of 700 cu. yds. in 10 hours The plant is a timber structure and cars are hauled up a short incline to the main crusher where they are dumped automatically. The stone passes through a No. 7½ and two No. 4½ gyratory crushers, and 3-ft. cylindrical screens of sizes from ⅜ in. to ½ in. The original cost of the machinery, the three crushers, screen, belts, etc., was $23,000. The cost of repairs given below is for new parts and does not include the labor of making repairs.

First year	$1,900.00
Second year	600.00
Third, fourth and fifth years	1,400.00
Total for five years	$3,900.00
Average per year	$ 780.00

The ¼ in. steel plates have been replaced about twice a year.

ESTIMATED COST OF QUARRY PLANT.

The following estimated cost of constructing and operating a quarry plant suitable for manufacturing ballast for railroads, is obtained from the Proceedings of the American Railway Engineering and Maintenance of Way Association, 1909.

Cost of Plant. From published figures, the cost of building a plant of 1,000 tons daily capacity, and its cost of operation to quarry, is as follows:

Capacity, 1,000 tons daily .... 300,000 tons annually	
900 cu yd. trap per 10-hour day .... 270,000 cu. yd. annually	
Crushers, 4, 250 ton Farrell, at $1,250	$ 5,000
Engines, 4, 60 hp , 14 x 12 at $500	2,000
Foundations	100
Belting, 13 in., 200 ft., at $2.75	550
Boilers, 2, 200 hp. and setting	7,500
Steam fittings	4,000
Boiler house	2,500
Engine house	1,500
Stack	2,000
Scales, 60 ft., including foundations and timber	1,225
Bins	600
Elevators with platforms, 4 at $1,500 (for tailings)	6,000
Pump for water supply, 5,500 gallons per hour	200
Tank, 50,000 gallons	1,200
Steam drills with tripods connecting hose, 20 at $245	4,900
Screens, rotary, 54 in., 4 at $950	3,800
Small tools, forges, bars, wedges, hammers, etc.	1,200
Derrick, small stiff leg	150
Total	$44,425
Contingencies, 8%	3,553
	$47,978
Land, 50 acres at $150 per acre	7,500
Cable railway and dump cars for haul to crusher, this being a varying item as quarry is worked	5,000
Total cost of quarry (1909)	$60,478

Cost of Operation of Quarry Plant

18 drillers at $3 per day, 300 days	$ 16,200
18 helpers at $1 75 per day 300 days	9,450
3 blacksmiths at $3 per day, 300 days	2,700
50 bar-sledgers at $1.75 per day, 300 days	26,250
60 coal loaders at $1 75 per day, 300 days	31,500
8 crusher men at $1 75 per day 300 days	4,200
1 quarry boss at $5 per day, 300 days	1,500
1 fireman at $2 50 per day, 300 days	750
1 engineer at $3 per day, 300 days	900
4 bin men at $1.75 per day, 300 days	2,100
1 scale man at $2 per day, 300 days	600
1 carpenter at $3 per day, 300 days	900
10 laborers at $1 75 per day, 300 days	5,250
1 clerk at $750 per year	750
Fuel, 2,700 tons of coal at $2 70	7,290
Oil waste, etc.	500
Dynamite, 7 lb. per cu. yd.; 270,000 cu. yd — 189,000 lb. at 15 ct.	28,350

Drill repairs, 1 machinist at $4		1,200
1 helper at $2.50		750
Supplies at $1.25 per month per drill		270
Blacksmiths included above		...
Total		$141,410
4% on first cost of plant	$2,418	
10% depreciation on machinery, except crushers	2,160	
16⅔% depreciation on crushers	833	5,411
		$146,821
Contingencies, 8%		11,750
		$158,571

This shows a cost per yard of 59 ct. (1909).

The following notes on the use of electric motors in gravel and stone plants appeared in *Engineering and Contracting*, Mar. 21, 1917. A small rock crushing plant driven by a 30-hp. motor, was turning out 6 cu. yd. per hour, and the motor not only drove the crusher and elevator, but was used to operate a winch for hauling cars of rock up an incline.

In and near cities, electricity can usually be purchased for power at prices under 5 ct. per kilowatt-hour. As a kilowatt is one and one-third horsepower, this is equivalent to about 4 ct. per horsepower-hour. But this does not mean that a 30-hp. motor would use $12 worth of current in a 10-hour day, even at 4 ct. a horsepower-hour; for the fact is that the full power of the motor is used only occasionally, and then for but a few moments.

In crushing and elevating a cubic yard of stone with a small jaw crusher about 15 lb. of coal are required for limestone, and about 18 lb. for tough trap. Considering the fuel losses involved in operating a 20-hp. boiler and engine, it is likely that a consumption of 900 lb. of coal per day of 10 hours indicates an actual 10-hour average of less than 10-hp. and perhaps as low as 6-hp. If, then, a 30-hp. electric motor averages only 7½-hp., or 75 horsepower-hours per 10-hour day, and if the price of the current is 4 ct. per horsepower-hour, the current cost is $3 a day.

A small crusher using 0.4 ton of coal a day at $4, requires only $1.60 for fuel; but this is only a "starter" in the expense of the steam power. There is the wage of the engineman, and the interest, repairs and depreciation of the boiler and engine, besides the cost of water, lubricating oil and other incidentals.

Outputs of Stone Crushers. Very little has appeared in print regarding the outputs of stone crushers, therefore the accompanying table showing the actual output of a number of stone crushers may be of interest:

	(1) Austin, in.	(2) No. 9 Gates — No. 6 Austin	(3) No. 5 Austin — No. 3 Gates	(4) No. 3 Austin
Size of crusher	7½	...	...	..
Size of broken stone, in.	2½	2½, 1½, 1½ and screenings	2½	2†
Number of men feeding crusher	2	1	2	2
Output in cu. yd. per 100 hr.	300	600	360	80 to 120
Average output in cu. yd. per 10 hr.	300	600	450*	..
Best output in cu. yd. per 10 hr.	450	750	500*	..

* Tons. † Nothing larger than will pass a 2 in. screen.

(1) Information furnished by the Breckenridge Stone Co., Breckenridge, Minn. The rock was a limestone. In addition to the two men feeding the crusher, about 45 others were employed by the company on other work about the crusher and quarry. (2) Information furnished by the Lake Shore Stone Co., of Belgium, Wis. The rock was a very hard dolomite limestone. The "one man" referred to in the table keeps the stone from "bridging" and keeps the hopper free. In addition, 44 men were employed loading stone into cars going to the crushers. (3) Information furnished by the Elk Cement & Lime Co., Petoskey, Mich. The crushers were side by side, the Gates being used for rejections. The rock was a hard limestone. The size of broken stone from the crusher ran up to 2½ in. (4) Information furnished by Holmes & Kunneke, Columbus, O. The rock was a hard limestone.

COST OF OPERATING A STONE CRUSHING PLANT BY CITY EMPLOYEES FOR THREE AND ONE-HALF MONTHS, BOSTON, MASS.

The Boston Finance Commission, in 1908, made a statement to the effect that in 12 years the city of Boston had wasted $1,000,000 by operating its own stone crushing plants instead of buying crushed stone from contractors for street work. Upon the request of certain city employees who professed confidence in their ability to turn this tide of extravagance, the mayor promised that for a limited time one crushing plant would be placed at their disposal to demonstrate their claims. The employees chose for the experiment the Church Hill Ave. plant and the Boston Finance Commission placed the work of recording the results in the hands of its engineers, Metcalf & Eddy, of

Boston. The full report of the engineers is given in Vol. III of Finance Commission's report recently made public and from this I take the following data:

The crusher plant occupies an area of 570,000 sq. ft., purchased in 1882 for $30,000 and having an assessed value in 1907 of $79,800. The tract is used in part for other than quarrying and crushing purposes. The plant consists mainly of a 30 x 13-in. Farrel crusher, a 72 x 16-in. Atlas engine, a 66-in. x 17-ft. tubular boiler, the usual elevators, bins, extra parts and tools, and of three large and one baby steam drills. The estimated cost of the plant was $16,653; interest was calculated at 4% and depreciation at 6.75% annually, which gives an amount of $1,791 which in the costs following was applied on a monthly basis. The charge for steam drills is based on a rental of 50 ct. per working day.

Force Employed. The force employed, with wages, was in general as follows:

	Per day
Labor at Ledge:	
1 sub-foreman at $3.50	$ 3.50
1 blacksmith at $3	3.00
1 blacksmith's helper at $2.25	2.25
3 steam drillers at $2.25	6.75
3 steam drillers' helpers at $2.25	6.75
10 stone breakers at $2.25	22.50
5 hand drillers at $2.25	11.25
1 powderman at $2.25	2.25
9 loaders at $2.25	20.25
Total	$ 78.50
Labor at Crusher:	
1 engineer at $3.50	$ 3.50
1 fireman at $3.25	3.25
1 weigher at $3.50	3.50
1 oiler at $2.25	2.25
3 feeders at $2.25	6.75
1 pitman at $2.25	2.25
Total	$ 21.50
Teaming:	
6 single teams at $3.50	$ 21.00
Total	$121.00

The force consisted largely of men who were in some degree skilled in rock work. The majority of the men were young and all were vigorous and skilled to such an extent that the force as a whole was skilful and efficient. There was a marked lack of interest on the part of some of the employees, which undoubtedly had its effect in reducing the amount of work done considerably below the amount which would be done under contract

conditions; on the other hand, it should be stated that some of the men took a lively interest in the work and did their full duty.

Preparatory Work. To put the plant in condition for the test there were expended the following amounts:

Items	Cost
Labor	$207.51
Teaming	7.50
Materials	38.34
Total	$253.35

This made a charge of $0.028 per ton of output during the test run. There were also $68.44 expended on repairs to scales which, being permanent repairs, were not charged to the test; they amount to a charge of $0 0076 or about ¾ ct. per ton of output. To house and prepare plant and tools for the winter after the conclusion of the test run cost $18 or $0.002 per ton of output.

Method of Operation. The quarry was first stripped of the earth overlying the ledge, after which holes were drilled in the rock by means of steam drills. These holes were loaded with dynamite and exploded, thus throwing out great quantities of stone. Much of the stone thus thrown out was in large blocks, which required breaking before they could be put into the crusher. In some cases this could be done by sledging and in other cases holes were drilled in them by means of a baby steam drill and hand drills, and the blocks cracked by use of dynamite. The stone thus prepared for the crusher was hauled to the loading platform, where it was dumped into the crusher and upon the platform. Men were stationed on the platform to feed the rock into the crusher. After passing through the crusher the broken stone was delivered by elevator to a revolving screen where it was separated into two grades; the very fine, or dust, being conveyed to one set of bins and the cracked stone to another set. These bins hold approximately 400 tons; and when the demand for stone for use upon the streets was not equal to the output of the crusher, and the bins were full, it became necessary to haul the balance of the output to a pile in the yard — about 2,259 tons of broken stone and 194 tons of dust being stored in the yard for this reason.

There was a misunderstanding with regard to hauling of stone from the bins to the pile in the yard, which caused a slight delay on July 1, 2 and 3, during a portion of which time the crusher was shut down. This delay amounted in the aggregate to not over two days of crusher service, during which time the quarrying was proceeding as usual. After July 3 there was no appreciable delay on account of causes beyond the control of the

foreman, except such occasional delays as are inevitable upon such work due to temporary disablement of the plant.

In this connection it should be noted that the capacity of the bins being only about 400 tons, they were sufficient only for about 2½ days output of the crusher as it was operated. The normal capacity of the crusher is claimed by the manufacturers to be about 250 tons per day, while the maximum output for any one day during this test was 225 tons.

During three weeks in July, three drills were operated, but this was found to be inadvisable because the force of laborers was unable to handle the rock as fast as it was blown out.

Periods of Operation. The results of this test have been divided into three periods, so that the comparative progress from time to time can be noted, as well as any improvement in the cost of operation. The dates of closing these periods were so selected that the amount of uncrushed stone which had been quarried was comparatively small, being in no case in excess of 200 tons.

First Period — The first period was from May 28 to July 13, inclusive, but included only that drilling and blacksmithing done up to July 6, inclusive, which corresponded to the output of the first period. The work and expense of this period may be summarized as follows:

Work Done:	
Stripping removed	174 tons
Holes drilled (2¾-in. diameter) by steam drills	1,069.5 ft.
Unbroken stone on hand at expiration of period (estimated)	200 tons
Broken stone ready for crusher at end of period	none
Total output of crushed stone during this period	1,651 tons
Cost:	
Labor and teaming per ton of output	$1.21
Materials used per ton of output	0.11
Total cost per ton of output	$1.32

In this summary, as in the summaries of the other periods, no account is taken of interest, depreciation or rental of plant, and certain general items of expense, or a few incidental supplies. The final summary covering the entire period, however, includes all of these expenses.

It should be noted, in the consideration of the first period, that the cost per ton of output includes all of the preliminary work, which amounted to approximately $0.15 per ton of the output of this period. Deducting the cost of the preliminary work from the cost per ton of output, $1.32, for the first period leaves the net cost for this period $1.17 per ton, which cost can be compared with similar costs for the second and third periods.

Second Period — The second period extended from July 14 to 11 a. m. of July 21, inclusive, and includes the drilling and blacksmithing applicable to this period. The work and expense of the second period may be summarized as follows:

Work Done:

Stripping removed	85 tons
Holes drilled (2¾-in. diameter) by steam drills	402.7 ft.
Unbroken stone on hand at expiration of period (estimated)	50 tons
Broken stone ready for crusher at expiration of period	none
Total output of crushed stone during this period	906 tons

Cost:

Labor and teaming per ton of output	$0.80
Materials used	0.08
Total cost per ton of output	$0.88

Third Period — The third period extended from 11 a. m. of July 21 to September 10, inclusive, and final date of the test. The work and expense of the third period may be summarized as follows:

Work Done:

Stripping removed	125 tons
Holes drilled (2¾-in. diameter) by steam drills	2,087.9 ft.
Unbroken stone on hand at expiration of period (estimated)	200 tons
Broken stone ready for crusher at expiration of period	none
Total output of crushed stone during this perod	6,397 tons

Cost:

Labor and teaming per ton of output	$0 76
Materials used	0.08
Total cost per ton of output	$0.84

It should be noted that the cost per ton of output during the third period was very close to that of the second period. The reduction in cost of stone crushed during the second and third periods below that of the first period, after deducting the cost of preparatory work, shows the result of the experience acquired by the force and improvement in organization.

Results of Entire Test. As already stated, the duration of this test was from May 28 to September 10, inclusive. The details of the cost of this test are given in Table B. The work accomplished during the test may be summarized as follows:

Work Done:

Stripping removed (a large part of the stripping had been done prior to the beginning of this test and is not included herein)	384 tons
Holes drilled (2¾-in. diameter) by steam drill	4,160.1 ft.
Unbroken stone on hand at beginning of test	none
Unbroken stone on hand at expiration of test (estimated)	200 tons
Broken stone ready for crusher at expiration of test	none
Broken stone on hand at expiration of test	none

Total output of crushed stone during test:

Dust	1,970 tons (22%)	
Stone	6,983 tons (78%)	
Total		8,953 tons

The cost to the city of producing the 8,953 tons of crushed stone, exclusive of $68.44 paid for permanent repairs to the scales, may be summarized as follows:

Cost:	
Labor and teaming	$0.881
Material used	0.106
Interest, depreciation and rental of tools and machinery.	0.069
Estimated equivalent cost of stripping done prior to beginning of test	0.025
Total cost	$1.081
Less cost of quarrying 200 tons of unbroken stone remaining at expiration of test	0.006
Net cost of crushed stone produced	$1.075

The major items of the foregoing summary may be subdivided into a comparatively small number of items which will show the cost of the various parts of the process of preparing crushed stone. (See Table A.)

TABLE A — SUMMARY SHOWING APPROXIMATE DISTRIBUTION OF EXPENSES AT CHESTNUT HILL AVENUE CRUSHER

	Cost	Cost per ton figured on output *	% of total charged to output
Quarrying and breaking ($50 having been deducted on account of unbroken rock remaining at the end of test)	$4,263.27	$0.476	44.3
Stripping	244.54	.027	2.5
Stripping done prior to test (estimated).	223.83	.025	2.3
Loading and delivery to crusher	1,980.99	.221	20.5
Crushing:			
Operation (including feeding crusher)	1,255.89	.140	13.0
Interest and depreciation on plant (3 months at $149.25 per month)	447.75	.050	4.7
Special expenses:			
Weighing stone	181.57	.020	1.9
Weighing stripping	19.67	.002	0.2
Hauling bins to pile (2,453 tons)	281.15	.032	3.0
Holidays	705.75	.079	7.3
Absent with pay	27.58	.003	0.3
Total charged to output	$9,631.99	$1.075	100.0
Permanent repairs to scales	68.44		
Total cost of test	$9,700.43		

* Output equals 8,953 tons of crushed stone (including dust). These units may be grouped as follows:

Quarrying and breaking	$0 749
Crushing	0 214
Holidays and absent with pay	0.082
Total	$1.075

Distribution of Cost of Foreman, Engineer, Fireman and Coal. The foreman devoted his time almost wholly to work of quarrying and breaking the rock for the crusher, and only a small portion to the operation of the crusher. We have, therefore, charged 30% of his time to the quarrying, 60% to the breaking and 10% to the crushing.

The steam for running the steam drills was furnished from the boiler, which constituted a part of the crusher plant. This boiler was under the general direction of the engineer and was cared for by a fireman. We have not charged any portion of the time of the engineer to quarrying, but have charged one-half of the time of the fireman as well as one-half the cost of the coal used.

Stripping. In certain places the ledge was covered with a layer of earth, which it was necessary either to remove before blasting or separate from the stones after blasting. A portion of this material had been removed from the ledge prior to the beginning of this test. The quantity of stripping removed during the experimental run was 384 tons, and our estimate of the amount which was moved prior to the beginning of the run (the cost of which should be charged against this experiment) would be 350 tons, or an amount nearly equal to that removed during the test. The cost of stripping done during the test was $0 637 per ton of soil stripped from the surface of the ledge. At this rate, the stripping done prior to the test would have cost $222.95 had it been done by the same force as a part of the experiment. This estimated cost of preliminary stripping amounts to $0.025 per ton of output.

Allowance for Rock Quarried but Not Blasted. As already stated there was no quarried rock on hand at the beginning of the test, but there was a quantity of about 200 tons remaining at its close. This should, of course, be credited to the experiment, which has been done by deducting the cost of quarrying it from the entire cost of the experiment. The cost of quarrying, including stripping, was about $0.25 per ton of rock quarried (8,953 tons of output + 200 tons unbroken rock = 9,153 tons quarried). The cost of quarrying 200 tons was therefore $50. which amounts to $0.005 per ton of output, which has been deducted from the total cost of output.

Resumé of Results of Test. This test has covered a period of time sufficiently great to demonstrate with accuracy the cost of producing crushed stone at the Chestnut Hill avenue crusher by day labor, under the conditions of the test. The force apparently consisted of men skillful and competent as could be selected from the entire organization of the division, and certainly gave evidence of being reasonably skillful and able-bodied. So far as

could be seen the foreman in charge of the work was given an absolutely free hand to organize his force as he deemed best, and to adopt such methods of handling the work as he might desire. With very slight and unimportant exceptions he was furnished with tools and supplies promptly, so that there is no reason to think that the output could have been increased by the improvement of conditions depending upon the co-operation of his superior officers in the Street Department. The net result of this test appears to be that the crushed stone was produced at a cost to the city of $1.075 per ton. These figures make no allowance for the cost of the quarry to the city, or the cost of administration and clerical services at the office, the latter of which is estimated at $0.05 per ton of output.

This experiment has been carried out under the very best of conditions. The quarry and crusher selected was the most favorable of any which the city has worked in the past, and produced crushed stone in 1905 more cheaply than any other crusher. During that year each of five crushers produced more than 30,000 tons of broken stone — the Bleiler, Centre Street, Chestnut Hill Avenue, Codman Street and Columbia Road crushers. Of these the Chestnut Hill Avenue crusher yielded the smallest output, although the cost per ton of crushed stone, $1,148, was lower than that of any of the others. The cost of producing crushed stone during the test was therefore reduced less than $0.08 below the cost of producing crushed stone at this crusher during the year 1905.

We have already called attention to the marked increase in efficiency of the force employed at the crusher during the second and third periods of the experiment. It is reasonable to inquire what the cost of the output would have been had all the work been done with the same efficiency. Such an estimate may be obtained by adding the cost of interest and depreciation, rental of machinery and tools, temporary repairs, and the stripping done before the beginning of the test, to the cost of any particular period, or an assumed cost. These items amount to over $0.10 per ton of output, so that it is reasonable to estimate the cost of operating the crusher at $0.95 to $1 per ton of output, based upon the efficiency attained during the second and third periods. This estimate, as in all other cases, does not include any charge on account of administration or office expense, nor does it include any charge for the cost of owning and maintaining the quarry.

Comparison with Market Prices of Crushed Stone. According to the report upon stone crushers already cited, the market price of crushed stone f. o. b. cars at the crusher is 50 cts. per net

ton. While it is not possible to determine accurately the market price of crushed stone f. o. b. cars Boston, under a contract similar to one which the city might negotiate, an estimate was given in the report, from which we have just quoted, amounting to \$1 per ton f. o. b. cars, or \$1.10 loaded upon wagons ready for hauling to the streets. It thus appears that the cost of crushed stone produced during this test was more than twice that of crushed stone f. o. b. cars at the crusher of a private corporation, or more than twice the price for which it could be produced at the Chestnut Hill Avenue crusher by a contractor, and that the cost was about \$0.025 less than the estimated contract price of crushed stone purchased in the local market and loaded upon wagons in Boston. These figures include no part of administration or office expenses, and no portion of the cost to the city of owning and maintaining the quarry. The administration and office expense would doubtless amount to as much as \$0.05 per ton of output, but we are not in position to make any estimate of the cost to the city of owning and maintaining the quarry.

We made the statement that the cost of crushed stone produced during the test was more than twice the price for which it could be produced at the Chestnut Hill Avenue crusher by contract, upon the assumption that conditions could be the same at this crusher as at the large commercial crushers in use.

As we understand the law, a contractor producing stone at this crusher for the use of the city would be obliged to confine the hours of labor to an eight-hour day, which would materially increase the cost of his work. It is also probable that the city would find it impracticable to take the maximum output of the crusher at all times, which would also be an important factor in the cost of operating this plant.

As stated in our report, the companies furnishing crushed stone within reasonable railroad distances of Boston appear to be very willing to dispose of their product at 50 cents per ton f. o. b. cars at crusher. We have one instance where crushed stone of one size (not the run of the crusher) was furnished at a cost of 55 cents per yard, or about 44 cents per ton delivered in place, including more or less freight expense. Obviously this stone was sold at a price at least as low as 40 cents per ton at crusher. It should be borne in mind, however, that these plants are very large ones, much larger than the Chestnut Hill Avenue crusher.

We have obtained the following data relating to the cost of operating a small temporary crushing plant on a trap rock quarry from April to October, 1906. The crusher was a 10½ by 18 inch Acme — a smaller outfit than that in use at Chestnut Hill

Avenue. The cost of producing the stone is given in detail in the following table:

	Cost	Cost per ton
Picking or drilling	$1,165.08	$0.0628
Breaking	1,937.23	.1042
Loading	1,843.99	.0994
Hauling	800.00	.0432
Crushing	1,229.73	.0662
Superintendence	437.10	.0235
Coal, oil, etc.	520 00	.0280
Dynamite and exploders	416.00	.0224
Total	$8,349.13	$0.4497
Plant rental ($210 per mo.)		.0792
		$0.5289

It appears from the foregoing table that the total amount of stone, 18,559 tons, was quarried and crushed for 45 ct. per ton, not including rental of plant. The rental of plant — actually a rented plant — was $0.0792, which added to 45 cents would make a total cost of 53 cents per ton.

It is important to note that during the test run of the Chestnut Hill Avenue crusher, the average output was 120 tons per day for three months (75 days) of actual operation of crusher. The nominal capacity of the crusher being 240 tons, it appears that the output was just one-half of the capacity. Under good management there should be no difficulty in turning out 240 tons of stone per day, and this could have been turned out during the test run without materially increasing the expense of the output, except for the cost of quarrying and breaking. These items would have been materially increased if the methods, discipline and character of labor remained the same.

In considering this subject, it should be borne in mind that there is not sufficient rock available at this location to warrant the establishment of a very large crushing plant. There is probably stone enough to supply the present crushing plant for a period of three or four years. (This is only a rough guess because no measurements have been taken upon which to base an opinion.)

From a further consideration of the statement in our report, which we have quoted above, we are of the opinion that a contractor might produce crushed stone at the Chestnut Hill Avenue crusher for about one-half of the cost of crushing stone during the test run. This, however, would probably not include the contractor's profit, and would necessitate his having an abundant market which would enable him to work the plant to its maximum capacity. It is not probable that the city could let this work

to a contractor for a sum as low as one-half the cost of the output during the test run for the reasons already given.

Cost of Hauling Crushed Stone to the Streets. An examination of the teaming checks covering a period of about three weeks, a portion of which was during and a portion after this test, showed that the cost of delivering stone amounted to about $0.40 per ton for the first mile, and about $0.10 per ton for each additional mile. Thus, with stone costing $1.075 per ton in the bin, the total cost to the city of such stone delivered to the street, at a distance of one mile from the crusher, would be $1.475 per ton, or at a point two miles from the crusher, $1.575 per ton. For comparison with contract prices, this figure should be increased by the amount of the cost of purchasing and maintaining the quarry and the proportionate cost of administration and office forces, not only on account of the quarrying and crushing, but also on account of teaming.

TABLE B — DATA ON COST OF OPERATING STONE CRUSHER AT CHESTNUT HILL AVENUE LEDGE, BRIGHTON, MASS., FROM MAY 28 TO SEPTEMBER 10, 1908, INCLUSIVE

Item	Total cost	Cost per ton figured on output
Labor:		
Supervision (foreman):		
Quarrying and breaking, 90%	$ 253.58	$0.028
Crushing, 10%	28.17	0.003
Buildings	93.36	0.010
Installing drilling plant	77.21	0.009
Removing and storing drilling plant	18.00	0.002
Operating drills	453.95	0.051
Furnishing steam for operating steam drills	114.16	0.013
Cleaning rock for drills and moving same	100.66	0.011
Blacksmith on ledge tools and pipe fittings	382.57	0.043
Blasting and care of explosives	182.29	0.020
Breaking stone	1,362.42	0.152
Hand drilling (block holes)	515.55	0.058
Loading stone	1,010.87	0.113
Removing and loading stripping	124.00	0.014
Weighing stone	181.57	0.020
Weighing stripping	19.67	0.002
Feeding crusher	331.61	0.037
Crusher operation (engineer, fireman, oiler and pitman)	539.74	0.060
Crusher repairs	55.54	0.006
Absent with pay	27.58	0.003
Holidays	705.75	0.079
Teaming:		
Buildings	4.50	0.001
Drilling plant	3.00	0.000
Hauling stone to crusher	929.28	0.104
Hauling stripping	111.47	0.012
Hauling product to pile	281.15	0.031
Total	$7,907.65	$0.882

Material, Rental, Interest and Depreciation

	Amount	Cost	Cost per ton figured on output
Ledge:			
Blacksmith's coal	1.32 tons	$ 5.54	$0.001
Battery repairs		4.86	0.001
Dynamite, 75%, 1½ in.	1,059.7 lb.	211.60	0.024
Dynamite, 75%, 1¼ in.	641.0 lb.	129.80	0.015
Dynamite, 60%, 1¼ in.	356.0 lb.	63.22	0.007
Black powder	6.0 lb.	0.66	....
Connecting wire	50.0 ft.	0.28	....
Electric fuses	389.0	...	....
8 feet long	49	2.13	....
10 feet long	19	0.92	....
12 feet long	257	13.67	0.005
14 feet long	64	3.71	....
Cotton fuse	3,522.0 ft.	10.15	....
Percussion caps	1,183.0	8.88	....
Stone dust for tamping holes	3.0 tons	3.00	....
Cylinder oil	19.75 gal.	6.32	....
Machine oil	3.75 gal.	0.64	0.001
Waste	22.0 lb.	1.65	....
Steaming coal	30.02 tons	126.11	0.014
Rental of small tools (at $0.05 per man per day) 1.815 man days (excluding blacksmith and helper) at $0.05		90.75	0.010
Rental and repairs of steam drills (including piping, hose, etc.), 153 drill days at $0.50		76.50	0.008
Buildings:			
Spruce lumber (3 in. by 4 in.)	337 ft. B. M.	8.43	....
Spruce lumber (⅞ in.)	430 ft. B. M.	11.18	....
Pine lumber (sheeting)	250 ft. B. M.	11.25	....
Rex roofing paper	3 rolls	6.75	0.004
Nails	30 lb.	0.75	....
Screws (No. 12, 1½ in.)	10	0.09	....
Strap hinges	1 pair	0.09	....
		$801.94	

Carried forward			$ 801.94	....
Crusher:				
Steaming coal	30.03	tons	126.10	$0.014
Cylinder oil	14.5	gal.	5 28	....
Machine oil	125.93	gal.	22.17	0.003
Waste	50.75	lb.	3.81	....
Sal soda	48.0	lb.	0.36	....
Rosin	1.0	lb.	0.04	0.001
Belt lacing	300.0	ft.	4.50	....
Sheet steel (11½ in. by 1¼ in.)	14.0	ft.	6.00	0.001
Crusher plates (two new, over half worn) at $211.80 less 50%			105.90	0.012
Rubber belting installed (new), $89.12, less 90%			8.91	0.001
Rental on small tools (at $0.05 per man per day), 250 man days (exclusive of engineer, fireman, oiler and weigher), at $0.05			12.50	0.001
Interest and depreciation on plant, three mo. at $149.25			447.75	0.050
Adjusting scales			4.76	0.001
Total			$1,550 51	$0.174
Labor and teaming			7,907.65	0.882
* Total charged to output			$9,458.16	$1.056
Permanent repairs:				
Repairs to scales			68.44	0.008
Total cost of test			$9,526.60	

* Does not include estimated cost of stripping done prior to beginning of test, amounting to $223.83, and does not include cost of quarrying 200 tons of stone remaining unbroken at end of test, amounting to $50.

A COMPARISON OF GYRATORY AND JAW CRUSHERS; THE FIELD IN WHICH EACH IS SUPERIOR

Jaw and gyratory crushers are the two distinct types of crushers extensively used for the preliminary reduction of rock and ore. The well known Dodge and Blake crushers are the best examples of the jaw type and have been widely used for many years. Aside from some modifications in the method of applying the thrust and in the construction of the frame, these machines as built today are similar to the early designs. The gyratory type of rock breaker was introduced about 1885. Its large capacity was its most attractive feature and led to its rapid introduction. The early designs were faulty in many features. There is an improved design which has become more or less standard with the several manufacturers. This is the suspended-shaft, two-arm spider, drop-bottom type, with cut-steel bevel gears, forced oil circulation, manganese-steel crushing head and concaves.

Since it is possible to purchase either type of crusher in almost any size and with the assurance that the design and construction are adequate for the work intended, the choice of type can be made strictly on the basis of suitability and economy. There are fads in machinery as well as in millinery. The rapid development of the gyratory crusher, and its success in meeting severe requirements have led many to advocate the complete retirement of the jaw type. Each type has a field in which it is superior, and it is easy to define the limits of each. There are certain advantages and disadvantages that are inherent in each type of machine, irrespective of size or service, and these are generally fairly well recognized. Of greater importance and less generally appreciated, are the characteristics of each machine for a particular size and service.

Table I has been prepared to show at a glance the comparative features of the two types over a wide range of sizes and services. All the machines quoted in the table, except the two largest sizes of gyratory crushers, are standard sizes. The weights, capacities, required power, etc., are those guaranteed by the manufacturers for average conditions with hard, friable rock. The machines quoted in the table to deliver a certain sized product are the medium sizes adapted to that product, as both larger and smaller machines, within small limits, could be adjusted to produce a certain size of material. The particulars of the 36 x 282-in. and the 42 x 345-in. gyratory crushers are only approximate, as the largest standard size manufac-

tured is 24 x 198 in. Gyratory crushers larger than 24 x 198 in. have been built to special design.

Size of Feed. Inspection of the compiled and calculated data in Table I reveals the following interesting comparisons: It develops that in each case the gyratory is a machine of greater weight, capacity and horsepower than the Blake crusher for the same size feed and product. The feed opening of the Blake type is rectangular, that of the gyratory is necessarily the segment of a ring. From this fact it follows that the weight and capacity of a gyratory crusher will increase more rapidly with an increase in the width of the receiving opening than will the Blake type. In other words, we may vary the width or the length of the feed opening in the Blake type independently of each other, while in the gyratory type the width of the feed opening controls the entire design, and the whole machine must be proportioned accordingly. This is an important characteristic and has great influence in defining the field of each type.

Weight, Capacity and Horsepower. Table II, which is computed from the data given in Table I, indicates a notable superiority of the gyratory type as regards efficiency of power consumption and capacity per ton weight of crusher. In all cases tabulated, except the first (crushing from 7 to 1½ in.), the relative capacity of the gyratory is greater than either the relative weight or required power. Referring to the third column of Table II, it appears that in this case the weight of the gyratory is 1.6 times that of the Blake crusher for the same size feed and product, but the capacity of the gyratory is 2.8 times that of the Blake, and the relative power required is only 1.66. This comparison between the two types is also emphasized by the values of capacity per installed horsepower which were computed for Table I. The gyratory is shown to vary from 0.58 ton per hour installed horsepower, in the smallest size tabulated, to 4.80 for the largest size, while the Blake has the values 0.50 to 2 for the same conditions. The greater duty per installed horsepower in the gyratory type is due to several reasons. A jaw crusher must break a rock by simple compressive force, high stresses being obtained by impact. The gyratory has the advantage of breaking a large number of pieces by beam action because of the concave shape of the shell and the convex shape of the crushing head. This action introduces both compressive and tensile stresses in the piece of rock, causing it to break with less exertion of force because the tensile strength of rock or ore is only a fraction of its compressive strength.

The gyratory is more economical of power owing to its continuous action. A jaw breaker consumes a large amount of

energy in overcoming the inertia of the heavy and rapidly reciprocating parts. Another feature which helps to account for the relatively large amount of power that is installed for Blake crushers is the intermittent character of the work. The demand is irregular, and may temporarily far exceed the average, so a crusher of the jaw type must be liberally equipped with power.

Comparison of Operating Advantages. Reference to Table I shows the marked advantage of the Blake over the gyratory type as regards the height of crusher. This is an important item, as it controls the height of buildings. In addition to the greater actual height of the gyratory it requires much clear headroom both above and below the machine for the necessary raising and lowering of the parts. The floor space occupied is about the same for either machine for a certain size feed and product.

The concave shape of the rigid shell of the gyratory, resulting in breaking some of the rock by beam action, causes the material to be more cubical in form than the product of a jaw crusher. For this reason the gyratory usually gives the most uniform product from a given ore or rock.

Other conditions being equal, there is less actual wear on the liners of a jaw crusher, because the tendency toward a certain grinding action cannot be entirely eliminated from the gyratory type. Owing to the conical shape of the concave liners of a gyratory they cannot be reversed when worn at the bottom. The plates for a jaw crusher can be arranged to be turned end for end when the lower part becomes badly worn. For these reasons the renewals for the gyratory type are a greater expense than in the jaw type.

Provided the feed is previously reduced to proper size, attendance is the same for one machine of either type, which gives an important advantage to the gyratory in those cases where its larger capacity enables it to replace two or more jaw crushers.

Repairs. Repairs are more difficult to make, and possibly more frequent, with the gyratory type. The critical mechanical feature of the gyratory is the eccentric drive on the lower end of the main shaft. With hard rock and heavy feeding it requires efficient lubrication to keep the bearings cool. A well designed Blake crusher is easier to keep in order. The introduction of steel castings for the main frame of the jaw crushers has increased the strength and lessened the weight of that important part. As regards vibration during operation the gyratory is superior, as it runs very steadily.

The consideration of relative merits for a specified capacity,

and the comparisons drawn therefrom are all on the basis of a given size of feed and product. It would be desirable to compare the two types on the basis of given capacity as well as size of feed and product, but this is not possible. When we designate the feed and product, the size and capacity of the appropriate crusher of each type is determined thereby, and these vary widely for the two types. The bearing that the required capacity has upon the comparison of merits, although left for the last, is all-important, as will be shown.

Consider the case in the first column of Tables I and II. This is the only case of those tabulated in which the gyratory does not excel in capacity per ton weight of machine. If, however, a particular installation required the capacity afforded by the 7 x 56-in. gyratory (seven tons per hour), it might be selected in place of two 10 x 7-in. Blake crushers, because of the economy of one machine, one foundation, and one attendant. If, however, advantages are to be gained, as in small stamp mills, by dividing the work between several small crushers so as to avoid conveying the crushed material and to gain bin storage without additional height, two small Blake crushers might be selected in preference to one gyratory. It should be noted that the relative weight of the two types is not an exact index of the relative first cost, because the gyratory crushers are sold at a higher price per pound than the Blake type. There are other factors affecting first cost besides the price of the machine at the manufacturer's works.

Rock Breakers vs. Bulldozing. Referring to the last columns of the tables, there is a most interesting case which is not generally well understood. We are dealing with large receiving openings and coarse crushing. During the last few years a demand has arisen for crushers of this magnitude in order to introduce economies in the mining and milling of ores. It has long been recognized that rock breaking is cheaper than stamp milling down to a size of about 1 in., and now it is beginning to be understood that rock breaking is cheaper than bulldozing and sledging pieces several feet in each dimension. This, of course, applies only to large-scale operations where the amount to be handled and the transportation equipment render such an installation feasible. To show the economies possible in this direction it may be noted that at the Treadwell mines in 1903 * the amount of powder used in stoping was 0.34 lb. per ton of ore mined, while it required 0.85 lb. per ton mined to bulldoze this rock after it was stoped. It required one man breaking rock

* The Treadwell Group of Mines, Douglas Id., Alaska, by R. A. Kinzie, Trans. A. I. M. E., 1904.

for each machine drill. Much labor was necessary on the feed floor of the crusher. The gyratory crushers in use did not receive large pieces. It is understood that improvements in this direction are now planned.

Returning to the tabulated features of the crushers with large feed opening, one is impressed at once with the enormous capacity and colossal size of the gyratory machines for this class of work. While the calculations show that the gyratory crushers in these sizes have marked advantages in efficiency, their tremendous size and cost are prohibitive unless their large capacities can be utilized. The 36 x 282-in. gyratory is estimated to have a capacity of 900 tons per hour to a 12-in. product, and the 42 x 345-in. 1,200 tons per hour to 16-in. It would be a remarkable mining or quarrying operation that would furnish large material at such a rate, and that is why we do not hear of gyratory crushers of such dimensions. Some machines have been built larger than 24 x 198-in., but they are not likely to come into general use. On the other hand the large Blake crushers are commonly built and successfully installed. Their capacity is usually in excess of the requirement, but, as is evident from Table I, not to the prohibitive extent that is true of the gyratory type.

Crushing Plant for 200-Stamp Mill. As an illustration of the application of the preceding data and conclusions, the design of a crushing plant for a 200-stamp mill will be considered. Assume a wide body of hard ore, which can be mined cheaply if the ore does not have to be blasted beyond what is necessary to break it from the solid, and adequate transportation facilities are provided to convey the large material to the crushing house. I further assume that a knowledge of the character of the vein and the general conditions of mining are such that it will be desirable to provide for receiving pieces up to 36 x 42 in. Assume that the stamps have a capacity of 5 tons per day, then for the 200-stamp mill 1,000 tons per day crushed to pass a 1¾-in. ring (equivalent to 1¼-in. cube) must be delivered by the proposed crushing plant. It is apparent that the ore must be crushed in stages. Since the initial crushers of large receiving opening will of necessity have a large capacity, it will be best to concentrate the crushing into one 8-hour shift, thus introducing economies in operation. This calls for a crushing capacity of 125 tons per hour.

In Table III the distribution of sizes in run-of-mine ore is obtained from experience. The percentages of the different sized particles in the product delivered by any particular crusher may be found by consulting the diagram shown in Fig. 113. For example, when crushing to pass a 6-in. ring, 81% will pass

a 5-in., and about 20% will go through a 1½-in. ring. This diagram was constructed by the Power and Mining Machinery Co., and is stated to be the result of the compilation of a large

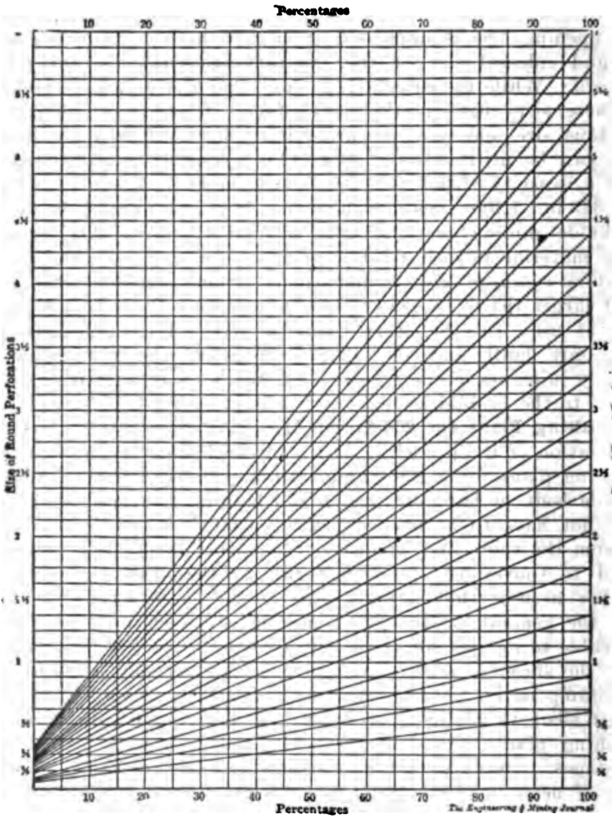


Fig. 113. Diagram Showing Proportions of Rock Crushed to Various Degrees of Fineness.

amount of experimental data. The results obtained are stated to have been uniform, and the diagram is recommended to be used to determine the percentages of certain sized products from any crusher, roll, or screen. The diagram is approximately

correct for hard friable ore, and proper allowance must be made if the rock has any inherent tendency to break in a certain way.

Taking the required capacities and duties as arrived at in Table III and referring to Table I, it is apparent that we would select the 42 x 36-in. Blake crusher for the initial breaker. This machine has excess capacity over what is required, but not such enormous excess cost and capacity as a gyratory for the same work. For the secondary crushing one 12 x 88-in. gyratory is strikingly superior, as it would require three 24 x 12-in., or two 40 x 12-in., or two 36 x 18-in. Blake crushers for the same capacity. For the final crushing two 10 x 80-in. gyratory crushers would be indicated.

If the ore foundation and conditions of mining and transportation were such that an initial crusher to receive pieces 24 x 36-in. was sufficiently large, it would be found, upon making a size analysis similar to that shown in Table III for 36 x 42-in. that one 36 x 24-in. Blake machine crushing to 4-in., followed by two 10 x 80-in. gyratory crushers each giving a product to pass a 1¾-in. ring, would meet the conditions.

In an installation of the size considered above, the crushing plant would be separated from the mill, the crushed product being delivered to the ore bins by conveyers. The large initial crusher must have a solid foundation, preferably resting directly on the ground. The large pieces to be handled make it imperative that the ore be dumped into a receiving hopper that feeds directly to the large crusher. If a gravity-plant site is not available or desirable, there is no difficulty in elevating the product of the initial crusher for further reduction.

The conclusions reached above are in accordance with the most advanced practice. The economy of breaking by crusher over bulldozing and sledging is beginning to be appreciated. Recent installations in South Africa employ large Blake crushers for initial breakers, followed by gyratory machines preliminary to stamp milling. A notable installation in the United States is that of a 60 x 42-in. Farrell-Bacon jaw crusher capable of breaking down to 16-in. the largest pieces of hard iron ore that can be handled by a 70-ton steam shovel. Other plants where economies have been secured by introducing large initial crushers of the Farrel-Bacon jaw type are the Granby mines, Phoenix, B. C., the British Columbia Copper Company and the Natomas Consolidated of California.

In conclusion it may be said that while each type has a field in which it is superior, no sharp lines can be drawn because of the many factors involved. It is believed, however, that with the aid of the data here presented an investigation along the lines

TABLE I.—COMPARATIVE FEATURES OF JAW AND GYRATORY CRUSHERS.

Crushing from	7 to 1½ in.		10 to 1¾ in.		12 to 2½ in.		18 to 3½ in.		24 to 5 in.		36 to 12 in.		42 to 16 in.	
Type of crusher	Blake	Gyratory	Blake	Gyratory	Blake	Gyratory	Blake	Gyratory	Blake	Gyratory	Blake	Gyratory	Gyratory	Blake
Size of feed opening in in.	10x7	7x56	20x10	10x80	24x12	12x88	36x18	18x136	36x24	24x198	42x36	36x282	60x42	42x345
Capacity in tons per hr.	4	7	12	30	25	70	60	130	85	400	160	900	300	1200
Weight in tons	4	8	9	18	15	24	29	50	30	95	55	200	100	300
Hourly cap.÷tons wt.	1	0.87	1.25	1.66	1.67	2.91	2.07	2.60	2.83	4.22	2.90	4.5	3	4
Installed horsepower	8	12	20	25	30	50	65	90	65	150	100	200	150	250
Hourly cap., installed hp.	0.5	0.58	0.60	1.20	0.83	1.40	0.92	1.44	1.31	2.67	1.60	4.5	2	4.8
Height in ft. (discharge spout to feed floor)	3	5½	3	7½	5	8	6	10	6	15	7	23	8	26
Width in ft. (including pulleys)	6½	10	7	13	8	13	13	13	13	20	13	27	15	30
Length in ft. (over all)	5½	5	9	6	10	6	12	12	12	12	15	18	16	21

TABLE II.—RELATIVE WEIGHTS, CAPACITIES AND HORSEPOWER.

The Blake Crusher being taken as unity in each case.

Crushing from	7 to 1½ in.	10 to 1¾ in.	12 to 2½ in.	18 to 3½ in.	24 to 5 in.	36 to 12 in.	42 to 16 in.
Relative weight of gyratory	2.0	2.0	1.60	1.72	3.16	3.65	3.00
Relative hp. of gyratory	1.50	1.25	1.66	1.39	2.32	2.00	1.68
Relative capacity of gyratory	1.75	2.5	2.80	2.17	4.72	5.62	4.0

indicated will quickly disclose the most desirable machine for any particular service.

Note particularly that the capacity in tons per hour of a crusher is a very uncertain quantity. The data in these tables have been gathered from various sources and are believed to be fairly accurate, but the author disclaims responsibility for what any one crusher may do on any particular job or on any particular kind of rock. The only safe course is to leave a liberal margin for contingencies. The guaranteed capacity of a manufacturer, even if accompanied by specifications and a contract, may mean only the guaranteed capacity for a run of an hour, and at the end of the hour the machinery may need to stand still for another hour to cool off. Crushers have been sold on such a basis more than once to the sad discomfiture of the contractor.

TABLE III.—SIZE ANALYSIS.

Crushing Plant Designed for 125 Tons per Hour.

	Tons per hour between			
	36 and 12 in.	12 and 3 in.	3 and 1¾ in.	1¾ in. and under
Run in mine	55	40	15	15
Feed to first crusher	55	..	..	..
Product of first crusher	..	30	15	10
Feed to second crusher	..	70	..	..
Product of second crusher	..	..	30	40
Feed to third crusher	..	..	60	..
Product of third crusher	..	..	..	60

In asking for estimates on crusher plants, the following information should be given the manufacturer:

The nature of the material to be crushed.

Tons or cubic yards to be crushed per day of ten hours.

Sizes into which the material is to be screened.

The different sizes to be obtained.

Storage capacity for crushed stone desired.

(This information will enable the determination of the proper length of elevator if one is needed.)

Whether power plant is wanted.

(If so, kind of power preferred, steam or electrical. If electrical, advise whether direct or alternating current, and voltage, phase and cycle.)

System of delivering rock to the crusher best fitted to local conditions:

A — incline and automatic dump cars.
B — Level with end dump cars and tipple.
C — Level with side dump cars.
D — Incline chute.

E — Incline track.
F — Dump cars on tramway.
G — Horse and cart.

Give an idea as to the character of the ground in the proposesd location; whether level or on a hillside. If on a hillside, give approximately the grade with a rough sketch of the site, if possible, showing the position of the quarry relative to the plant and the position of railroad tracks.

Answers to the above questions, together with such other suggestions and directions as may be offered by a prospective customer, will facilitate very much the preparation of plans and the selection of appropriate machinery for the plant.

SECTION 29

DERRICKS

Sulky Derrick having a capacity of 2 tons, timber of 4 by 4 in. by 12 ft. spruce or pine including two single blocks and 50 ft. steel wire rope or 100 ft. manila rope costs $142. (Fig. 114.)

Four Leg Derrick 4 by 4 in. by 12 ft. of spruce or pine, with iron drum and gear, but without blocks or rope costs $75.

Three Leg Derrick 3 by 3 in. by 11 ft. of spruce or pine with wooden drum 6 by 30 in. and no gear, blocks or rope costs $38.

Tripod Derrick constructed of black steel pipe and steel drop forged fittings costs as follows (no blocks or rope included):

Capacity in lb.	Weight in lb.	Price
1,000	45	$10.00
2,000	100	17.50
3,000	165	27.30

Setter Derrick equipped with malleable and steel fittings costs as follows:

Capacity	Type	Length	Price
3,000	Top point	18	$48.40
4,000	Regular	18	56.00

If longer lengths are desired add $1.10 per ft., for more capacity add $2.20 per 1,000 lb., fish tackle to swing derrick in and out, with 5 blocks and 50 ft. rope, $7.20.

Light Pole Derrick capacity 1,400 lb. with 100 ft. cable and winch, not geared, complete with no guy lines, 18 ft. $44.

Pole Derrick complete with winch, 125 ft. steel cable and block:

Capacity	Length	Price
2,500 to 3,000	18	$ 52.50
4,000 to 5,000	18	74.00
8,000 to 10,000	18	126.50

For additional lengths add $1.10, $1.65 and $2.20 respectively per ft.

A-Frame Derrick. For hoisting and setting timbers, columns, beams, etc. Complete with 125-ft. cable, block, geared winch, height 21 ft., capacity 2,500 lb., price $79. Combination pole and derrick $86.

Tower Boom with 14-ft. boom $60.50. Add $1.10 per ft. for additional lengths up to 24 ft. Fittings $45.50 per set.

Circle Swing Builder's Derrick. Capacity 1,000 lb., weight 200 lb., can be operated by hand, horse or power. Height 7½ ft., boom extends 5 ft., equipped complete with 110-ft. steel cable.

Hand power	$49.50
Hand and power	51.20

Fig. 114. Sulky Derrick.

Capacity 1,800 lb., weight 275 lb., height 8 ft., swing 10 ft., equipped with 125 ft. cable.

Hand power	$62.80
Hand and power	65.50

Capacity 2,500 lb, weight 350 lb., height 8 ft., swing 10 ft., equipped with 150 ft. cable.

Hand power	$75.00
Hand and power	78.10
Steel boom extra	4.15

Stiff Leg Derricks. Complete fittings without timber for derrick to be operated by a double drum steam or electric hoist cost as follows:

Three part line

Capacity in tons	Size of mast in inches	Price f. o. b. factory
3	10	$375
6	12	475
10	14	600
15	16	850
	Five part line	
3	10	$440
6	12	550
10	14	650
15	16	850

Guy Derrick. Complete fittings without timber for guy derrick to be operated by a double drum hoisting engine cost as follows:

Three part line

Capacity in tons	Size of mast in inches	Price f. o. b. factory
3	10	$325
6	12	390
10	14	525
15	16	740
	Five part line	
3	10	$350
6	12	450
10	14	675
15	16	775

Another make of derrick costs as follows:

GUY DERRICKS FOR STANDARD WORK

Capacity in tons	Approximate shipping weight of fittings in lb.	Price f. o. b. New Jersey
3– 4	3145	$ 490
5– 7	4235	630
10–12	5360	820
15–20	6850	1,040
20–25	8975	1,320

GUY DERRICKS FOR BUCKET WORK

Loaded bucket in lb.	Approximate shipping weight of fittings in lb.	Price f. o. b. New Jersey
6000	4655	$ 660
8000	5145	710
10000	6555	950
12000	6555	950

STIFF LEG DERRICKS FOR STANDARD WORK

Capacity in tons	Approximate shipping weight of fittings in lb.	Price f. o. b. New Jersey
3– 4	3540	$ 540
5– 7	5115	710
10–12	6770	980
15–20	8230	1,280
20–25	11975	1,690

Stiff Leg Derricks for Bucket Work

Loaded bucket in lb.	Approximate shipping weight of fittings in lb.	Price f. o. b. New Jersey
6000	5414	$ 760
8000	5955	820
10000	7965	1,080
12000	7965	1,090

The prices of the stiff leg and guy derricks include all necessary fittings, bolts, sheaves, blocks and 12 ft. all steel bull wheels with guide sheaves, but do not include any timbers or wire rope.

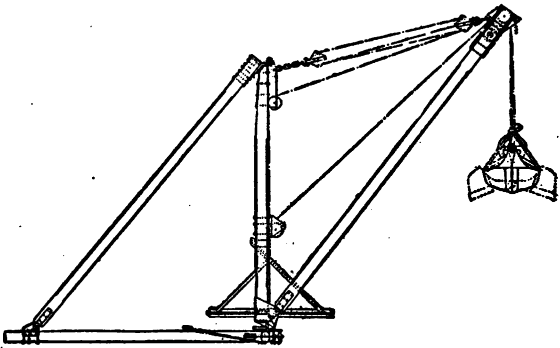


Fig. 115. Stiff Leg Derrick.

Jinniwink Derricks

Capacity in tons	Approximate shipping weight of fittings in lb.	Price f. o. b. New Jersey
3	1300	$330
5	1430	340

The price of the three ton size includes a pair of 9 in. double sheave manila rope blocks and the manila rope snatch block for the boom fall line, which is usually snagged to a cleat on the A frame when the derrick is in operation. Two 9 in. double manila rope blocks and a single drum purchase hand power are also included for the main fall. No timbers or rope are included.

The price of similar material for the 5 ton size to be operated by an engine, which is the usual rig, is given above. The price for this derrick to be operated by hand power is approximately $390.

IRONS FOR POWER-OPERATED STIFF-LEG DERRICKS

The following list, to accompany Fig. 116, enumerates the most important metal parts of stiff-leg derricks to be operated by power. It does not include guide sheaves, blocks, or other running gear.

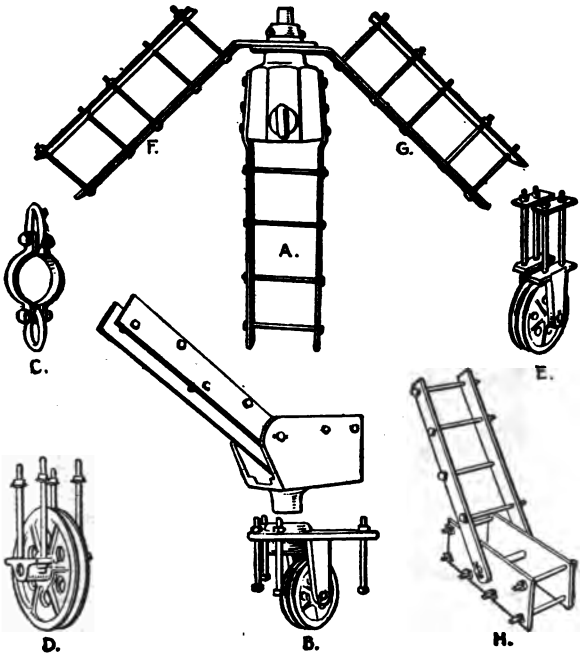


Fig. 116. Iron Work Complete for Power Stiff-Leg Derrick — As Regularly Furnished.

A. 1 Mast Top with straps and gudgeon pin.
B. 1 Mast Bottom complete with step, double sheaves and strap for boom.
C. 1 Flat Bolted Boom Band with 2 links.
D. 1 Single Boom Sheave with boxes, for center of mast.
E. 1 Double Sheave Mast Bracket.
F. 1 Top Stiff Leg Iron.
H. Lower Stiff Leg Irons (two of these furnished), and all necessary bolts.

In building 1,000 ft. of 15-in. pipe sewer at Big Rapids, Mich., a trench 4 ft. wide and about 15.5 ft. deep was dug in gravel and boulders. About 8 cords of stone, many of them large size

and near the bottom of the trench, were removed. A fuller description of this work is in Gillette's "Cost Data," p. 817.

The first 5 ft. were taken out with a scraper and a team and driver. The remainder was removed in buckets with a derrick having a capacity of 1,500 lb., 18-ft. mast and 18-ft. boom, with sheaves arranged for three lines in the bottom tackle and

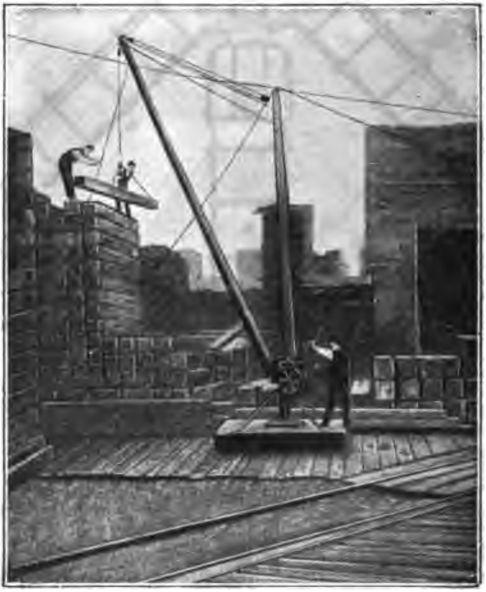


Fig. 117. Parker Derrick No. 4 — Hand Power.

three lines in the hoisting tackle. About 50 ft. of sewer were completed per day at the following cost:

	Per day
1 foreman at $2.00	$ 2.00
1 scraper team and driver at $3.75	3.75
1 man holding scraper at $1.50	1.50
1 man dumping scraper at $1.50	1.50
2 men pulling sheeting and carrying it at $1.50	3.00
1 man pulling sheeting and carrying it at $1.50	1.50
1 horse and driver on haul line at $2.50	2.50
4 men filling two 1/6 cu. yd. buckets at $1.50	6.00
1 man laying pipe at $2.00	2.00
1 pipe layer's helper at $1.50	1.50
Total	$25.25

This gives a cost of 50.5 cents per lin. ft. of sewer. The actual cost of excavation was 20 cents per yd. for scraper and 12.6 cents for derrick work. The derrick was moved two or three times a day, which took about seven minutes each time.

Mr. Saunders gives the following detailed cost of a large quarry derrick with a capacity on a single line of 20 tons.

Timber for mast 24"x 24"x 75'	$ 45.00
Timber for boom 65'	28.00
Expense of delivering timber	16.50
Carpenter work on mast and boom at $12.50 a day	25.00
Derrick irons, sheaves	219.00
2,400' of best galvanized 1" iron rope for 8 guy	237.00
Thimbles, clamps, etc.	25.00
500' steel hoisting rope, 1⅝"	240.00
Labor on dead men, 4 men, 2 days at $1.40	11 20
Labor raising derrick, 8 men, 2 days at $1.40	22.40
Labor fixing guys, 8 men, 2 days at $1.40	22.40
Total (prior to 1912)	$891.50

On railroad work in Newark it took six men and a foreman one day to move a stiff-leg derrick with a 50-ft. boom 150 feet and one day to set it up, at a total cost of $24.00. This includes moving the engine and the stone used to weight the stiff legs. Two guy derricks with 70-ft. masts and 80-ft. booms were used for two years in building a concrete filter. During that period they were erected once, moved five times, and finally removed once at a cost of $1,400, an average of $100 per move. As a rule, however, a guy derrick can be shifted more easily than a stiff-leg derrick, as there are no stones to be handled. Above costs were prior to 1912.

Derricks should be provided with a bull wheel where possible, as the wages of two tagmen will soon pay for it.

Sizes and prices of steel bull wheels complete with braces:

Diameter, feet	For booms, length in feet	Weight complete	Price
8	40	1600	$300
12	60	2000	475
14	70	3000	550
16	80	3700	650

A derrick formerly known as the Kearns derrick was used in the construction of a 14-ft. concrete sewer at Louisville, Ky. The sewer was 4,230 ft. long and had an average depth of 39.3 ft.; the average number of yards per ft. was 26.5. The derrick excavated to within 14 ft. of the bottom, and a Potter machine excavated the remainder and carried it to the rear for backfill. The derrick operated a ¾-yd. clamshell bucket, which loaded into wagons for spoiling or into Koppel cars for backfill. The output was about 1,500 cu. yds. per week.

The machine consisted of a stiff-leg derrick mounted on a turn-table. The power plant was a 7 x 10 in. engine with three drums, and a 30 hp. boiler. The entire outfit cost about $6,500, prior to 1912.

Method of Depositing Material by Derrick Beyond Reach of Boom. The following notes by Mr. M. A. Milliff appeared in *Engineering and Contracting*, Feb. 2, 1916.

The fitting of the derrick and the mode of operation are shown by the diagrams 1 to 5 in Fig. 118. Three lines are employed. From the back drum the load line runs through a sheave at

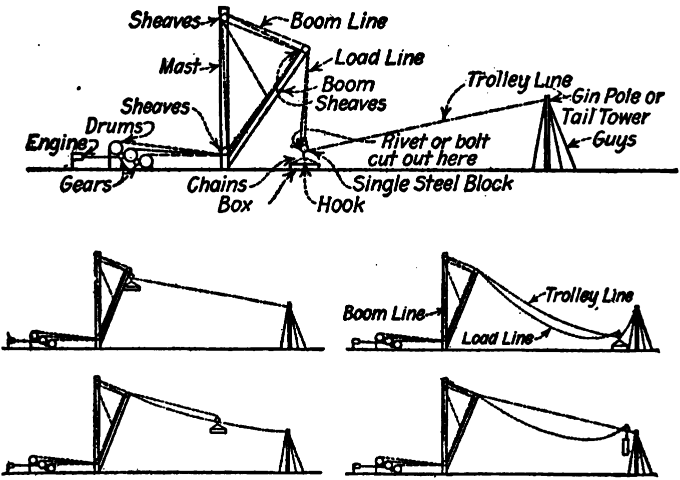


Fig. 118

the mast bottom, thence through a sheave at the boom end, and its end is made fast to a steel block. From the middle drum the trolley line runs through a stream at the mast bottom, thence through the boom end stream, thence through the steel block and thence to the top of the gin pole where it is made fast. From the first drum the boom line runs through a sleeve at the mast bottom, thence to another at the mast top, thence to boom end sleeve, thence back to a second sleeve at the mast top and thence it is dead ended to the middle of the boom.

If a two-drum engine is to be used, the boom line can be carried on a hand crab, as only an occasional change in the position of the boom is necessary. The block used is an ordi-

nary single-sheave steel block with swivel hook. It is necessary to cut out the rivet or bolt in corner facing derrick, as trolley cable would rub on it during operation.

The material box is an open-end skip of 1-cu. yd. capacity, fitted with chains — one to each back corner and one to the middle of the front end. The front chain is fitted with a trip-hook. The ring in end of the chains is hooked in the hook in the block.

For the gin pole or tail tower, 26-ft. yellow pine piles were used, set up on a suitable foundation to prevent sinking into the ground under strain. Old hoisting cable was used for guys.

1 shows position when picking up the loaded box. The operator hoists the load by picking up on the load line, bringing the trolley line tight as the load is raised and swinging the derrick around so that the boom will face the gin pole. The load is hoisted to the desired height and the trolley line tightened as shown in 2. At this point the operator holds the trolley line tight with the foot-brake and then releases friction on the drum carrying the load line, which allows the box to trolley toward the gin pole as shown in 3. When the box is over desired dumping place the foot-brake holding the trolley line tight is released, allowing the box to drop as shown in 4. The hook on the front chain is then tripped and the box is dumped by bringing the trolley line tight, as shown in 5. The box is returned by pulling in on the load line and slacking off on the trolley line, bringing the box back into position for loading.

The derrick can be swung around by swinging gear or swinging engine and bull wheel as in other derrick work. It was found, however, that it was necessary to put an attachment on the end of the boom to prevent the trolley line from jumping out of the sheave when worked at an angle greater than 60 degrees each side of the line from the derrick to the gin pole.

Two derricks were used on this work, both being 10-ton steel guy derricks with 90-ft. masts and 75-ft. booms. One derrick was equipped with a three-drum 7¼ by 10-in. hoisting engine with swinging gear attached, and the other with a two-drum 8¼ x 10-in. engine with independent swinging engine. The 8¼ x 10-in. engine did the work more satisfactorily than the smaller engine.

The trolley line arrangement has been operated for a distance of 300 ft. with a 12-ft. drop. The load necessary to operate it depends on the condition of the hoisting engine and the ease with which the drums overhaul, but it is believed that a 2,500-lb. load will be found necessary to operate trolley on this flat slope.

In bailing slush out of a hole where five men filled the boxes

with buckets and one foreman, one hoisting engineer and a laborer to dump the boxes completed the crew, 137 boxes have been moved in eight hours. In harder digging, where it was necessary to load the boxes with shovels, an average of 70 boxes in eight hours has been maintained with the following crew: One foreman; one hoisting engineer; and eight laborers.

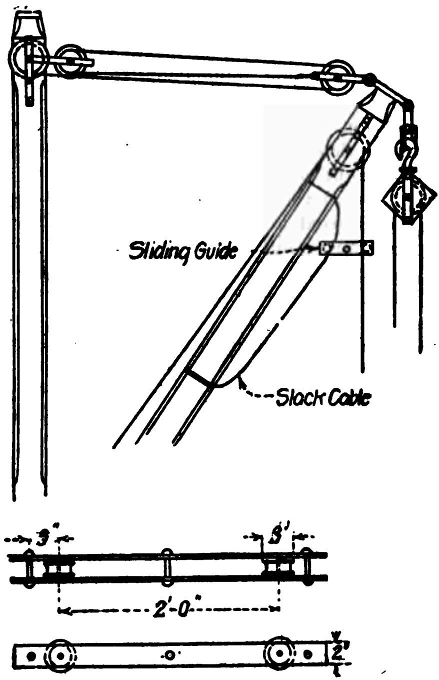


Fig. 119. Derrick Arranged to Prevent Twisting of Fall Block.

Method of Keeping Fall Block on a Derrick from Twisting and Swinging. As shown by Fig. 119 a cable is fastened along the boom with about 2 ft. of slack. One end of the cable is fastened as close as possible to the sheave near the end of the boom, and the other end of the cable is fastened about 10 or 15 ft. from the base of the boom. Two flat pieces of iron about ¼ x 2 in. x 2 ft. are fastened together with two sheaves between them, one sheave at each end, as shown in the sketch. This is then

put on the derrick with the slack cable and the fall line passing between the sheaves, as shown in the operation of the derrick. This guide slides up and down on the cables. When the boom is being lowered the guide slides up. Besides preventing the twisting of the blocks it also serves, to some extent, in preventing the load from swinging.

Floating Derricks. A floating derrick was purchased by the city of Chicago in 1905 at a cost of $5,287.26. It was used on the hydraulic filling of the Lincoln Park extension in 1910 for various purposes. It was in commission ten hours per day and was operated by a crew consisting of an engineer, fireman and a varying number of deck hands, usually four. The cost of operation during 1910 was as follows:

Hours in commission	1,783.50
Labor of operation	$1,871.29
Fuel and supplies	599.07
Insurance	100.00
Labor repairs	268.70
Towing	17.62
Total	$2,856.68
Total cost of repairs	286.32
Total cost of operation	2,570.36
Total cost per hour	1.60
Total cost per day	16.00

During 1911 the derrick was in commission for 440 hours with a crew of two men, and for 1,254 hours with a crew of six men. The cost of operation and repairs for the 1,694 hours in service is given as follows:

COST OF DERRICK OPERATION AND REPAIRS

		Per hour
Operation		
Labor, watching	$ 178.67	
Fuel	237.68	
Supplies	244.63	
Insurance	96.50	
	$ 757.48	$0.45
Repairs		
Labor	$ 188.70	
Material	140.75	
Teams	14.00	
	$ 343.45	$0.20
Total operation and repairs, excepting operating labor	$1,100.93	$0.65
April 1 to Aug. 1, 440 hours.		
Operating labor	$ 568.55	$1.29
Fuel, supplies and repairs	.....	0.65
Cost per hour, 440 hours	.....	$1.94

After Aug. 1, 1,254 hours.		
Operating labor	$3,155.95	$2.52
Fuel, supplies and repairs	.....	0.65
Cost per hour, 1,254 hours	.....	$3.17
Total cost for year (1911)	$4,825.43	

SECTION 30

DIVING OUTFITS

A diver's outfit consists of a metal helmet or head covering, a breast plate, an air-tight diving suit, and shoes with weights. Weights are also attached to his waist to overcome buoyancy. The helmet always has one window in front, usually one on each side, and sometimes one near the top. The air hose runs from the pump to a valve either in the helmet or breast plate. Besides this one, a safety and a regulating valve for controlling the pressure are provided. The diver is raised or lowered by a rope attached to his waist called the safety line.

The air pump is always operated by hand power, may have from one to three cylinders, may be single or double acting, and of either the lever or fly-wheel type.

The following are the prices of several diving outfits. The equipment furnished with outfit number 5 is itemized; that furnished with the other outfits is similar but more extensive. In outfit No. 1 for two divers the equipment is duplicated, with the exception of the pump which is designed so that it may be used for either one or two divers.

There is a large number of extra fittings and equipment not included in the following outfits, such as electric lanterns and generator outfits, chafing clothing, cushions, pads, etc.

Helmets cost $175 to $205; suits $60 and $65; air pumps $225 to $725; hand dynamo with cable, lamp, complete $140. Electric breast lamp fitted with lens and 16 c.p. lamp, 125 ft. of cable $40. Submarine electric lantern $75. Magneto for blasting 20 holes $35. 40 holes $65. (See Blasting Machines and Supplies.)

Diving Outfit No. 5. This is designed to be used in very shallow water and for light work. It is for one diver only and will supply air in 30 ft. of water. It is made up as follows:

1 air pump, two cylinders, single action	$210.00
Pump on plank, without case, $180.	
1 improved diving helmet, three lights, complete	175.00
1 rubber diving dress	60.00
100 ft. of standard white air hose, two pieces, couplings	60.00
1 set diving weights, horseshoe pattern	20.00
1 pair diving shoes, lead soles	24.00
1 pair cuff expanders	5.00

1 diver's knife	12.00
1 pair rings and clamps	6.00
1 pair rubber diving mittens	5.00
1 life or signal line, 100 ft.	4.00
1 pair chafing pants	8.00
1 helmet cushion	4.00
6 extra bolts and nuts for helmet	3.00
1 set couplings (spare)	3.00
½ yd. rubber cloth for repairs	1.50
1 can rubber cement for repairs	1.00
2 ft. snap tubing	1.20
1 cutting punch	1.25
	$603.95

Price of complete outfit with pump on plank and without case, $573.35. Shipping weight of the above outfit is 350 lb.

Diving Outfit No. 4 is adapted for examinations and all work of brief duration in shallow water, as for water works, sewer departments and contractors. Is for one diver only and will supply air to 50 ft. of water. Complete outfit with single cylinder, double acting air pump, helmet, dress, etc., $662.20. Shipping weight 475 lb.

Diving Outfit No. 3 is especially designed for river and harbor work. Used by contractors, engineers, railroads, etc. With two cylinder, single action pump and complete equipment for one diver, $1073.35. Shipping weight 1,000 lb.

Diving Outfit No. 2 for special work in deep water for one diver, is designed for general work, deep sea or shallow water, harbor and dock work, wrecking, salvage, etc. Will supply air to 160 ft. of water. Price of complete outfit with three cylinder single action pump, $1,203.35. Shipping weight 1,100 lb.

Diving Outfit No. 1A. Complete with one cylinder, double action air pump for one diver in 95 ft. of water $923.35. Shipping weight 1,000 lb.

Diving Outfit No. 1. For general use of contractors, divers, etc. Complete outfit for one diver, $1,298.35. Shipping weight 1,200 lb. Complete outfit for two divers, $1,871.70. Shipping weight 1,600 lb.

All the foregoing prices are f .o. b. Boston or New York.

The manufacturer states that outfit No. 2 or No. 3 is generally called for by contractors.

SELECTION OF DIVING APPARATUS

In the selection of an outfit the following points should be given careful consideration:

1. Duration of the work.

2. Whether it is to be conducted with long or short spaces of time intervening.

3. Depth of water.
4. Whether the outfit is to be used on rocky or sandy bottom.
5. Character of the work.
6. Selection of the pump.

The selection of the pump is the most important point, and in view of recent experiments and tests of the work that can be accomplished by a diver at different depths, buyers are apt to order pumps of too small capacity. A volume of air equal to that ordinarily breathed at the surface (about 1½ cubic feet per minute) should be introduced into the helmet. The volume of free air that must be taken in by the pump at the surface to deliver 1½ cubic feet per minute at 5 fathoms is about 3 cubic feet; at 16 fathoms, about 6 cubic feet; at 27 fathoms, about 9 cubic feet, etc.

The following table gives pressure in pounds per square inch at a given depth of water:

30 feet,	12¾ pounds.	150 feet,	65¼ pounds (usual limit).
60 feet,	26¼ pounds.	180 feet,	78 pounds.
90 feet,	39 pounds.	210 feet,	91¼ pounds.
120 feet,	52¼ pounds.	240 feet,	104 pounds.

NOTES ON DIVING

The following notes have been taken from a manufacturer's catalog: Due to the strain and excitement of submarine work the diver is not quite in normal condition. The greater his exertions the more air he will need, as is the case when a man runs rather than walks.

The average male adult breathes at the rate of 15 inhalations per minute or approximately .25 cubic feet, taking 30 cubic inches as the average inhalation. Exhaled air contains on the average about 79.1% nitrogen, 16.5% oxygen and 4.4 carbonic acid gas.

The superficial area of an average man is 2,160 sq. in., at atmospheric pressure (15 lb. per sq. in.) the total pressure on a man is about 32,400 lb. At a depth of 33 ft. of sea water the pressure would be about 65,000 since the pressure increases nearly half a pound per sq. inch for each foot in depth. The pressure is balanced by the air supplied from pumps or compressors. Pressure gauges are generally graduated to show pressures in excess of atmospheric pressure, that is, the reading of the gauge is always about 15 lb. less than the absolute pressure. For ordinary diving work the above data will be entirely adequate.

In computing the air necessary for a diver it must be remembered that the volume of a gas under pressure varies inversely

with that pressure. (Boyle's Law.) Experiments show that the same volume of air should be maintained for all depths, that is, the supply must be proportional to the depth. For instance, if a diver is receiving 1½ cu. ft. in a unit of time at the surface, he must be receiving 3 cu. ft. in the same unit of time when he is at a depth of 33 ft. where the pressure is 15 lb.; at 165 ft., 9 cu. ft.; and at 297 ft., 15 cu. ft. of air. However if two or three times this amount of air be available, so much the better.

The minimum circulation of air through the helmet should be equal to:

$$1.5 \times \left[1 \quad \frac{\text{Depth in feet}}{\text{33 (34 if fresh water)}} \right]$$

$$\text{or } 1.5 \times \left[1 \quad \frac{\text{Number of lb. per sq. in. excess pressure (water) exerted by}}{14.7} \right]$$

or 1.5 times the number of atmospheres absolute pressure, cubic feet (measured at atmospheric pressure) per minute.

On entering the water the increased pressure drives the air from the lower portion to the upper part of the diver's dress, forcing the water against the lower part of the diver's body. If the escape valve is wide open the diver will probably feel the effects of the increased pressure and find some difficulty in breathing. The escape valve should be regulated so that an amount of air sufficient to overcome the pressure of the water will be retained in the dress and helmet.

The formation of nitrogen bubbles in the blood and tissues has been found to be the chief difficulty in deep diving. This danger can be obviated to a large degree by reducing the time spent in deep water and by making the descent and the first part of the ascent as quickly as possible. The last part of the ascent being made in fixed stages. The old theory that a diver should descend slowly has been exploded, for the diver will absorb nitrogen as the descent is made. Occasional distress occurs in rapid descents from pressure on the ear drums altho few good divers are troubled in this respect. During test conducted by the U. S. Navy all the divers were able to descend at the rate of 100 ft. per min.

Sometimes on arriving at the surface, a diver will experience difficulty in breathing and even become unconscious. If partly dressed he should be dressed at once and lowered to slightly more than one half the depth at which he was working and brought

up according to the tables.* The fact that he is unconscious makes no difference as this is the only way to save his life. When possible another diver may be sent down to tend the afflicted diver. Occasionally paralytic symptoms appear within a few minutes and sometimes as late as a half hour after the diver comes to the surface. The diver should be lowered and promptly brought back to the surface. If the diver is afflicted with the "bends" it will be found that these pains invariably pass off shortly, but immediate relief may be obtained by recompression followed by proper decompression. If he fails to answer signals he should be brought to the surface and artificial respiration applied."

* The Tables referred to, together with full instructions for using diving equipment, may be had from the manufacturer from whom the equipment is purchased. The foregoing notes on diving were abstracted from the catalog of Andrew J. Morse & Son, Inc., Boston, Mass. A full understanding of the use of diving equipment is absolutely necessary in this work.

SECTION 31

DRAG SCRAPER EXCAVATORS

(See Grading Machines.)

Under this heading are included all machines that fill buckets by dragging them along the ground. The simpler form of drag scrapers pick up the load, when being pulled toward the power unit, carrying the material in and ahead of the bucket. The bucket is then pulled back along the ground, and the operation repeated. With this type of scraper a "dead man" is put down and a line is fastened from the front of the bucket to the drum of the power unit, the line then going to a block on the dead man and to the rear of the bucket, so that the bucket is pulled back and forth by operating the drums.

Drag scraper excavators in general use are so controlled that the bucket is lifted above the ground, after being filled by scraping, and carried to the point of discharge. It is then dumped and returned, above the ground, to the point of excavation, lowered, and the operation repeated. This type of apparatus may be operated by a cableway, or self-contained machine. The cableways may be run with steam, electricity, or gasoline and may be stationary, or operated on rails. The self-contained machines are furnished with wheel, caterpillar and walking traction.

Bottomless Drag Scrapers hold from 0.5 to 7 cu. yd. and cost from \$300 to \$700. These scrapers are furnished with renewable cutter edges or teeth. Gillette says it requires a 35 to 80 hp. engine, 7/8 to 1 in. haul back line and 1 to 1¼ in. pulling line. With a 600 ft. haul approximately 15 trips per hr. should be made; with a 1,500 ft. haul about 6 trips. An output of about 500 cu. yd. per 9 hr. day can be averaged under favorable conditions.

This type of excavator will work to any depth and to any width and is adaptable to railroad work, stripping, irrigation ditches, river work, trunk sewers and work of like nature.

COST OF LEVELING GROUND WITH AN ELECTRIC DRAG SCRAPER.

Prior to 1912.

By James C. Bennett.*

The gold-dredging industry of California has given rise to a method of leveling ground that offers possibility of a considerably more general application than has been developed to date. The method, by the electric drag scraper, was originated in the Oroville field, where one of the dredging companies was required by the municipality to restore to an approximately level surface the ground that it had dredged within the city limits. Although some such leveling had been done by means of horses and scrapers, prior to the development of the electric drag scraper, it had been on small tracts only, and the cost had been almost prohibitive when the acreage involved amounted to more than one or two, or possibly three, acres.

A few months ago, the writer was called upon to arrange for grading a piece of ground. The work involved leveling down some piles of gravel to a grade suitable for building lots, making a roadway 60 ft. wide by 600 ft. long, half the width being a cut and the remainder a fill, and filling a large water hole to a grade above the level of standing water. Practically all previous work had been done by owners on force account, and, since the only object to be gained was to level the ground to any convenient grade, no attempt had been made to determine the yardage involved, hence no unit cost was available. The nearest approach was based on the cost per acre, which ranged from $175 to $200 per acre. In this, however, it was impossible to secure any suggestion even as to the approximate yardage represented.

In preparation for the proposed work, an attempt was made to determine the approximate yardage involved by a rough measurement, but without success. Some idea may be gained of the difficulties of making measurements on ground of this character from the statement that, for purposes of railroad construction in this field, it was found necessary to make cross-sections at 10-ft. intervals. An estimate based on previous acreage costs would be unreliable in this instance, owing to the necessity of working to grade. The writer and the contractors made a joint estimate of the time required to do the work. As the approximate daily

* Abstracted from *Engineering News*.

expense was known within fairly narrow limits, this afforded the most equitable basis of cost.

Seventy-five working days was agreed upon as sufficient time to complete the work. This was to include lost time on account of repairs, setting deadmen, moving lines and blocks, and moving machine from one position to another. During, and upon completion of the work, the following data were obtained:

Daily Expenses

1 Winchman	$ 5.00	
2 Helpers @ $2.50	5.00	
1 Horse (for moving lines, etc.)	1.00	
133.33 kw.-hr. @ 2¼ ct.	3.00	
Making a total daily cost of		$ 14.00

Time Required

No. days actually scraping	62	
No. days moving lines and winch and making repairs	10	
Making total days worked		72
No. working days in which no work was done.	10	
Making elapsed working time days		82

Costs

72 days @ $14.00	$1,008.00	
Repairs, materials only	35.00	
4-horse team, man and scraper, surfacing street grade, 1 day	10.00	
600 ft. second hand, 1¼-in. hauling line	54.00	
600 ft. second hand, ⅞-in. back line	30.00	
Depreciation at 10%	120.00	
Making a total cost of		$1,257.00

In the foregoing figures, as will be noticed, a charge is made against the job for the full cost of the ropes. In doing this, the job is being charged with a little more than is really legitimate, as the same ropes are good for probably two to three thousand yards additional. Also, the depreciation charge is probably liberal, as there is very little severe wear and tear on anything but the scraper.

A close tally was kept of the number of trips made, or loads hauled, and, from time to time, the loads were measured. An average of 1¼ cu. yd. per trip is believed to be very nearly correct. The total amount of material moved, based on the number of trips made, was 15,300 cu. yds. The actual cost per cubic yard was thus 8.2 cents.

For the 62 days of actual scraping, the average running time was seven hours per day.

Average length of haul	**175 ft.**
Average day's duty	**247 cu. yd.**
Largest day's duty	**425 cu. yd.**
Average hourly duty	**35.2 cu. yd.**

The equipment consisted of a winch, motor, transformers, drag scraper, hauling and back lines, and snatch blocks. The winch was of the type commonly used on gold dredges, having been taken from a dismantled dredge. It was driven by a 50-hp. motor, through one belt and two gear reductions, giving a rope speed — both lines — of about 130 ft. per minute. There was but one drum on the winch, having a central flange to separate the ropes. The hauling speed proved a very satisfactory one, but the return rope should have been speeded up to at least 150 ft., and possibly would have worked satisfactorily at 175 ft. per minute. In fitting up the winch for the scraping work, the original cast-iron frame was discarded in favor of a much lighter timber

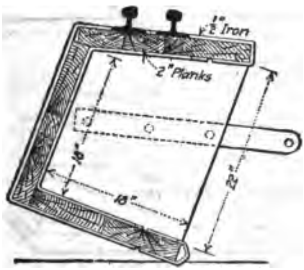


Fig. 120. Section Through Bucket Used on Electric Drag Scraper.

frame, in which skids were made a part of the machine. For transmitting power from the transformers to the motor, an armored three-conductor cable was used. This permitted the winch to be moved about the field with its own power, and made unnecessary any moving of transformers. During the execution of the work, the winch was moved twice, that is, had three positions, including the original.

The transformers were not disturbed after being originally connected, as the nature of the ground permitted the selection of a location within reach of the several positions of the winch. The power company made no extra charge for running the necessary pole line — some five or six hundred feet — and connecting the transformers and motor.

The scraper was made of 2-in. planks, the cross-section being of the shape shown by the accompanying sketch (Fig. 120). The

inside measurements were 18 x 18 in. and it was 12 ft. wide. A little experimenting was necessary at the beginning of the work to determine the correct angle at which the bail irons should be set. It was found necessary to make one or two changes of this angle during the progress of the work, owing to different conditions of the ground and material. The planks were well strapped together with bar steel, and the ends were of steel plate. One, and some of the time two, pieces of rail were fastened to the top of the scraper for added weight. Both hauling and back lines were second-hand mine hoist ropes, in

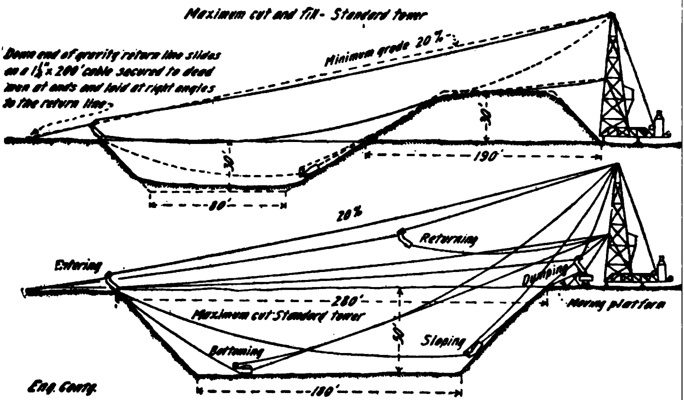


Fig. 121. Sketches Showing Operation of Field Tower Excavator.

very good condition, but discarded for mine use in compliance with state mining laws. With the exception of one or two small portions of the work, the hauling line ran over only one snatch block, while the back line ran over three blocks a large portion of the time. A fairly liberal use was made of deadmen, it being more economical than to move the winch.

A Dragline Scraper Excavator having novel features was used on one of the New York State Barge Canal contracts held by the Atlantic, Gulf & Pacific Co., New York City. This excavator is known as a Field Tower Scraper, being named from its inventor, the superintendent for the company at Comstock, N. Y. As shown by Fig. 121, the essentials of the excavator are a movable tower, a cableway and hauling lines and a special scraper bucket. The tower carries a double drum engine. From one drum a line passes up the tower and over a sheave located from one-

fourth to one-third its height and thence down to the bucket. This is the hauling line. The second line passes up and over a tower head sheave and thence to a pulley block on the opposite side of the prism. This pulley block rides on a ½-in. cable about 200 ft.

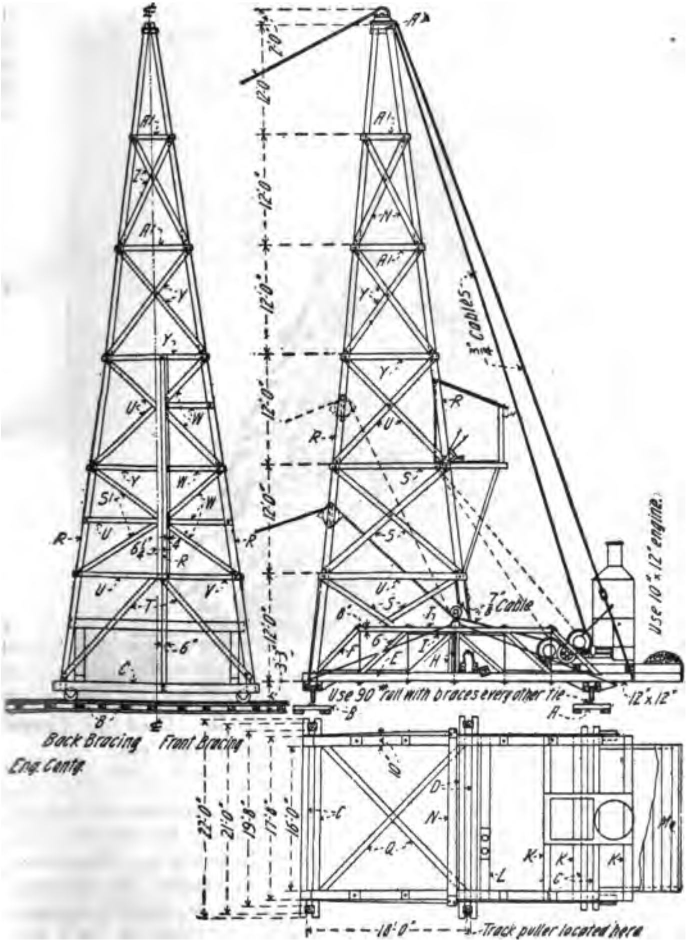


Fig. 122. Details of Tower for Field Tower Excavator.

long, stretched parallel to the prism between two deadmen, moving along the cable as the tower moves. This second line is the cableway on which the scraper bucket travels back and forth across the canal, being pulled toward the tower by the hauling line and sliding back by gravity.

Fig. 123. Sauerman Type of Movable Tower, Used on Levee Work, Deepening and Widening Rivers, etc.

The Tower. The tower is a framed timber structure of height suitable to cover the width of the excavation for which it is intended (the standard tower being 75 ft. in height). This tower rests on a trussed platform or car which carries the hoisting engine, coal and other supplies. The tower is rigidly secured to the truss and guyed by back stays to the projecting back end of the platform. The platform or car runs on four solid double

flange cast steel wheels, 16 in. in diameter and 4 in. tread. The track consists of two 90-lb. rails each spiked to 6 x 8 in. x 4 ft. ties spaced 2 ft. apart and bolted to two 2 x 12 in. x 30 ft. planks. The engine may be any good make 10 x 12 in. engine with double drums and two niggerheads. The hauling line is ⅞ in. and return cable is ¾ in.; 18 in. sheaves are used.

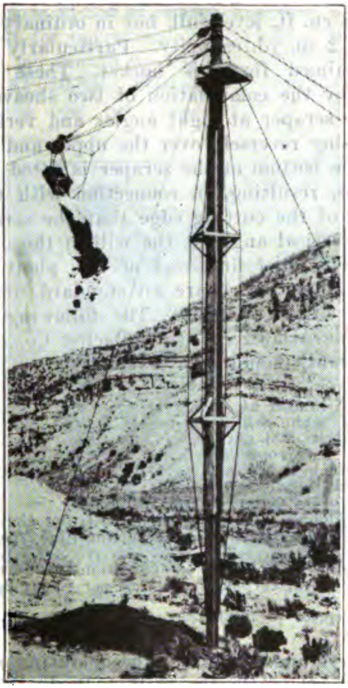


Fig. 124. Type of Built-up Timber Mast. Photo Taken on Reservoir Cleaning Job.

The tower is moved forward or back by a 1½ in. manila line secured to a deadman suitably placed, passing through sheaves secured to the platform and around the niggerhead. The track is also moved ahead by the same means, the deadmen being dispensed with and line passing around the end of a boom which

is a part of the tower. The line around the niggerhead is operated by the fireman.

The operator's cabin is placed up about one-third the height of the tower in full view of the work, and the engine is manipulated by suitable levers and brakes connecting the operating cabin with the engine.

Scraper Bucket. The distinctive feature of the excavation is the scraper bucket which is shown by Fig. 125. This bucket has a capacity of 48 cu. ft. level full, but in ordinary material it will "crown up" to 2 cu. yd. capacity. Particularly easy and certain control are claimed for this bucket. These advantages are brought about by the combination of two sheaves placed at the rear end of the scraper at right angles and vertically to it, the return line passing reversely over the upper and under the lower sheave, while the bottom of the scraper is fitted with two curved cradles or shoes, resulting, in connection with the pulling line, in such control of the cutting edge that the scraper can be sustained at any vertical angle at the will of the operator.

Cost Data. The chief first cost of this plant is in the hoisting engine and cable, which are all standard commercial designs and usable for other purposes. The following is an estimate furnished by the Atlantic, Gulf & Pacific Co. of the cost of a tower scraper plant, including everything:

5,080 ft. B. M. lumber at $38 per M.	$ 193.04
360 ft. B. M white oak at $45 per M.	16.20
540 lb. iron bolts and nuts at 6 ct.	32.40
120 ft. ⅝-in. wire rope backstays	13.20
2 ⅝-in. turnbuckles	.80
1 headblock sheave and bearing	10 00
1 hauling sheave and bearing	4.00
1 8¼ x 10 Lidgerwood double drum hoisting engine	1,089.00
1 scraper bucket, complete with cutting edge, sheaves, etc.	300.00
Labor directing based on condition in northern New York, carpenters at $2.50 per 8-hour day	200.00
Total (prior to 1912)	$1,858.64

The following is an estimate of the operating cost of the plant also furnished by the Atlantic, Gulf & Pacific Co.:

Item	Cost per month
Wire rope	$160.00
20 tons coal at $4	80.00
Oil, waste and repairs	15.00
Total (prior to 1912)	$255.00

To this is to be added the labor cost. Each shift requires the following force:

1 foreman at 37½ ct. per hour	$ 3.00
1 engineer at 37½ ct. per hour	3.00
1 fireman at 22 ct. per hour	1.76
1 signal man at 25 ct. per hour	2.00
5 laborers at 20 ct. per hour	8.00
And an additional	
4 laborers at 20 ct. per hour	6.40
Total (prior to 1912)	$24.16

Assuming 26 working days and two shifts per day, the labor cost for one month is $1,256.32, which, added to $255 given above, makes a total cost for operation of $1,511.32. Assuming interest on plant at ½% per month we have an additional $9.30, making the grand total $1,520.62. Assuming an output of 700 cu. yd. per day we get a cost per cubic yard of 8.4 ct. This cost

Fig. 125. Scraper Bucket for Field Tower Excavator.

included, however, a proportion of the field office expenses. In regard to the life of the cables used, the Atlantic, Gulf & Pacific Co. writes:

"While the life of the wire rope used depends almost entirely upon the character of material to be excavated; in clay and loam, the plant working two eight-hour shifts per day, 26 days each month, excavating approximately 700 cubic yards per day, will use 800 to 1,000 ft. of wire rope per month."

Cost of Drag Scraper Buckets. The following table gives the cost of these buckets without teeth.

Capacity in cu. yd.	Weight, lb.	Price f. o. b. factory
¾	1900	$ 700
1	2500	780
1½	3200	860
2	4850	1,043
2½	5850	1,190
3	6550	1,360
3½	7200	1,510

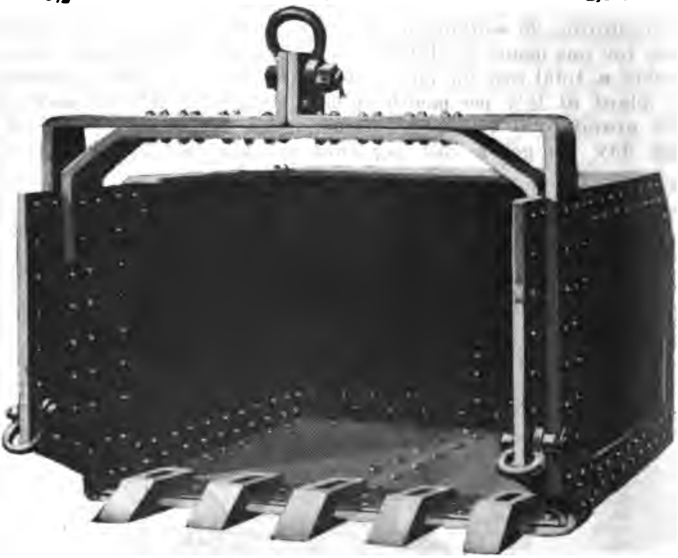


Fig. 126. Heavy Excavator Type Bucket for Digging Hard-Packed Material.

If teeth are wanted a set of 4 for the ¾, 1 and 1½ size costs $82. For the 2 and 2½ size the cost is $112, and for the 3 and 3½ size, $180.

Cost of Cableway Drag Scraper Outfits. The following is the cost of bucket and carrier equipment including excavator bucket, carrier, traveler block, dump block, stop button and patented chain mountings.

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. Chicago
⅓	1200	$ 550
½	1900	775
¾	2900	1,010
1	3400	1,275
1½	4600	1,550
2	4950	1,710

A 500 ft. span dragline cableway excavator including bucket and carrier equipment, mast top assembly, bridle and anchor attachments, wire rope specifications, without necessary engine or timbers for mast or tower costs as follows:

Capacity in cu. yd.	Approximate shipping weight in lb.	Price f. o. b. Chicago
⅓	5500	$1,670
½	7100	2,120
¾	9300	2,660
1	12000	3,280
1½	16000	4,310
2	22000	4,975

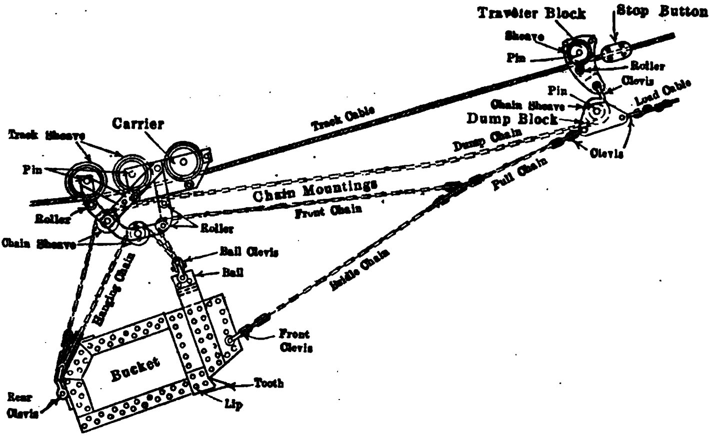


Fig. 127. Assembly of the Sauerman (Shearer and Mayco Type) Dragline Cableway Bucket, Carrier and Mountings.

Built up timber masts for use with dragline cableway excavators have the following specifications:

Length of span in ft.	Size of mast in in.	Height of mast in ft.	No. of ft. B. M. of timber	Cost of hardware
300	16 by 16	50	2500	$380
400	16 by 16	64	3000	450
500	16 by 16	72	3500	460
600	16 by 16	80	4000	470

The following notes on a cableway drag scraper by Mr. J. R. Slattery appeared in *Engineering News Record* May 25, 1916. This installation is illustrated by Fig. 130.

The first cost of a machine of this type, erected and equipped, is about $45,000. It has a clear span of 662 ft. The towers are

BILL OF MATERIAL FOR FIELD TOWER

Mark	No.	Size	Length Ft.	Length In.	Ft. B. M.	No.	Size of bolts	Washers
A	4	4"x 12"	30	0	480	44	⅝"x 10" wood	88 cut
B	22	6 x 8	4	0	352	16	1 x 20	32 cast
C	4	8 x 12	22	0	504	8	1 x 20	16 cast
D	2	6 x 12	22	0	264	8	1 x 24	16 cast
E	2	12 x 12	36	0	864	8	1 x 16	16 cast
F	4	8 x 12	8	0	256	8	⅞ x 6'–6" long	14 1"x 6"x 12"
G	8	6 x 12	7	0	336	2	1⅛ x 7'–6" long	4 1"x 10"x 12"
H	4	4 x 10	5	0	67	..	....	3 1"x 22"x 12"
I	12	3 x 10	5	0	150	4	2"x 19'–0" long	....
J	2	8 x 12	22	0	352	12	1"x 20" wood	24 cast
K	3	12 x 12	18	0	648	4	1"x 20" wood	8 cast
L	1	10 x 12	18	0	180	8	1"x 14" wood	16 cast
M	11	3 x 12	16	0	528	..	....	....
N	1	10 x 10	20	0	167	3	1"x 14" wood	....
O	1	8 x 8	24	0	128	1	1"x 12" wood	2 cast
P	1	3 x 6	18	0	27	8	1"x 16" wood	16 cast
Q	2	8 x 10	22	0	322	..	....	....
R	..	2 x 8	..	0	2200	150	½"x 8" wood	300 cut
						24	½"x 12" wood	48 cut
S	12	3 x 6	20	0	360			
T	4	6 x 6	16	0	192			
U	18	3 x 6	18	0	486			
V	1	6 x 6	19	0	57			
W	14	3 x 16	10	0	210	16	⅝"x 14" wood	
X	1	6 x 6	12	0	36	150	½"x 9" wood	350 cut
Y	11	3 x 6	16	0	264			
Z	8	3 x 6	14	0	168			
A1	8	3 x 6	10	0	120			
A2	1	12 x 12	3	0	36	4	¾"x 16" & 2¾"x 3"x 4'	
"	4	4 x 8	3	0	32	4	¾"x 2'–6"	....
"	1	4 x 12	6	0	24	2	¾"x 3'–3"	18 cast
"	2	7 x 8	3	0	30	2	¾"x 20"	
Housing 1" and 2"x 4"					3000	..	....	
					12840			
Wheel boxes						32	¾"x 17"	36 cast
Idler						4	¾"x 12"	
Cable clips						12	¾"	
Turnbuckles with eyes						2	¾"	....
Back stay						..	160' ⅞" cable	....

Lever connections not included

of steel, 85 and 45 ft. high respectively, and support between them a 2¼-in. cable. On this cable travels a carriage which carries a 3-yd. drag-line bucket. The carriage is moved back and forth by means of an endless line, operated by one of the drums of the main engine. The bucket is loaded by means of a cable which leads from the front end of the bucket to another drum on the main engine, and is lifted by means of a cable which is attached to the bail of the bucket and runs thence around a sheave on the carriage, over a sheave at the top of the head tower and thence to a third drum on the main engine.

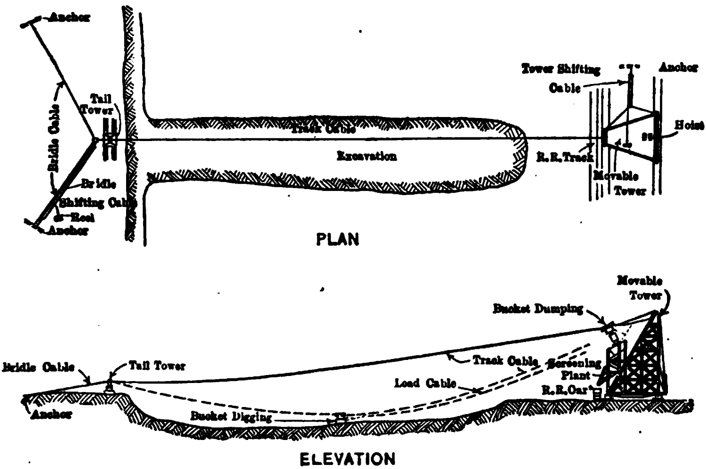


Fig. 128. Diagram of Dragline Cableway Excavator Installed for Excavating Sand and Gravel from Shallow Deposits in River 600 ft. Wide. Includes a 100 ft. Self-Supporting Movable Tower on which is Mounted the Hoisting Engine and Gravity Screening Equipment.

A pull of 50,000 lb. for loading the bucket is developed by means of a special engine, which operates a haul-down rope which runs from the drum of this engine around one sheave of a double tandem block (the second sheave of which rides on the drag or loading line) and thence to the frame of the tower.

The bucket is dumped at will by means of a haul-down rope which pulls down on the dumping line attached to the back of the bucket, and running thence to the conveying drum, thus accelerating the movement of the rear of the bucket relatively to that of the front end and consequently causing the back end

of the bucket to lift and the material to dump. This haul-down rope is operated by means of a piston and steam cylinder. A special engine is provided on the head tower to move the same. The tail tower is moved by means of a friction drum operated by the conveying line.

The crew of this machine consists of one foreman rigger; one operator; one rigger's helper; one engineman; one fireman; one

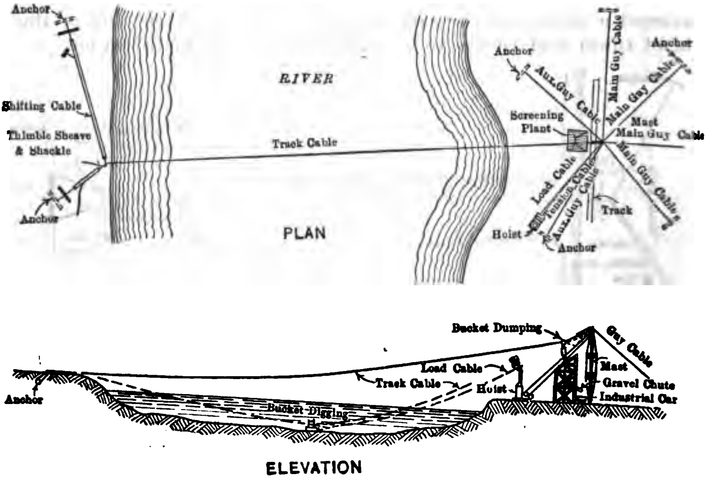


Fig. 129. Diagram of Sauerman Dragline Cableway Excavator Installation for Digging Gravel from River Bottom and Delivering Material to Gravity Screening Plant.

signalman; eight laborers (trackmen), three on tail tower and five on head tower; three laborers (dressing levee); three teamsters (ploughing, dressing levee and hauling supplies).

WORK DURING 1915 BY LIDGERWOOD LEVEE BUILDER

Month	Yardage placed during month	Cost per cu. yd.	Yardage placed since work began	Average cost per cu. yd.
April	5,211	$0.1850	5,211	$0.1850
May	13,239	.1386	18,450	.1518
June	20,050	.1548	38,500	.1534
July	23,850	.1126	62,350	.1378
August	19,050	.1490	81,400	.1404
September	2,600	.7047	84,000	.1579
October	22,800	.1041	106,800	.1464
November	28,500	.1108	135,300	.1389
December	18,600	.2253	153,900	.1494

The very high costs of September were due to practically the entire month having been lost on account of high water, wet pits and delays incident to renewing the main cable — the latter due purely to bad management. The high cost of December was due

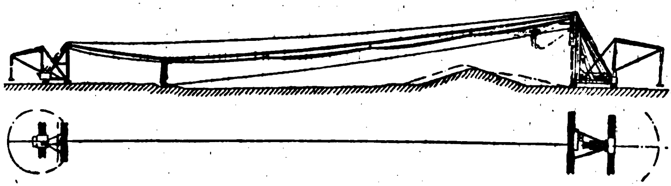


Fig. 130. Lidgerwood Drag-Line Cableway Excavator Used in Vicksburg District to Build Mississippi Levees.

to a flood and to the necessity of stopping work some days before actually drowned out, in order to prepare for a prolonged high water. Shortage of coal and the holiday season also cut down the output of this month. The past season was an exceptionally bad

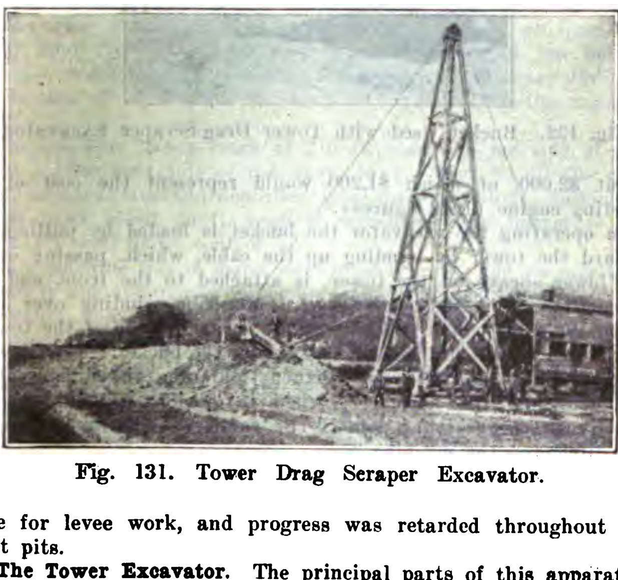


Fig. 131. Tower Drag Scraper Excavator.

one for levee work, and progress was retarded throughout by wet pits.

The Tower Excavator. The principal parts of this apparatus are a hoisting engine; a tower 65 ft. high, guyed to cables ex-

tending to the ground on each side, where instead of being stationary, they slide on other cables stretched parallel to the ditch and fastened to deadmen, thus giving stability to the tower, while allowing it to move parallel to the ditch; the scraper bucket in which the earth is moved; and cables for operating the bucket. The machine is built upon a platform and is moved on rollers by winding a cable fastened at one end to a deadman. A more efficient provision for moving the machine would doubtless result in considerably reducing the cost of operation. The operation of the machine is illustrated in Figs. 131 and 132. Its cost was about $1,500 prior to 1912. With the strengthening of parts necessary to fit it for extra heavy work the cost would be

Fig. 132. Bucket Used with Tower Drag-Scraper Excavator.

about $2,000, of which $1,200 would represent the cost of a hoisting engine (1912 figures).

In operating the excavator the bucket is loaded by pulling it toward the tower by winding up the cable, which, passing over the lower sheave on the tower, is attached to the front end of the bucket. The bucket is then dumped by winding over the drum the cable which passes over the sheave on top of the tower and which is attached to the back end of the bucket. The bucket is returned to the ditch by further tightening the upper cable and loosening the lower one, then it quickly slides back by gravity to the starting point. The earth is deposited between the ditch and the machine.

The following is the cost for each eight hour shift in operating this machine:

Engineer	$ 3.00
Fireman	2.00
Foreman	3.00
Signal man	2.00
Cable shifter	1.60

Horse and man, moving track	3.00
4 Laborers, at $1.60 each	6.40
1½ tons of coal to the shift, at $3 per ton	4.50
Total (prior to 1912)	$25.50

If to this is added $1.50 per shift for maintenance, depreciation, interest, and repairs at the rate of 50% per annum on the original cost of the investment, the total cost per shift is $27.

By arranging for the operator to work from a station in the tower, where the work would be in full view, the signal man would be eliminated, and by placing the machine on a track with an arrangement for moving the machine ahead on the work by means of gearing attached to the axles probably two or three more men could be dispensed with, thus further reducing the cost.

The bucket used on this machine had a capacity of about 2 yd., but in ordinary operation at least 3 yd. were carried at each load. While in operation about 1 bucketful was excavated and deposited in each forty seconds. This would make a rate of 4 cu. yd. a min., and the contractor was of the opinion that he could maintain an output of 1,000 yd. per eight-hour shift for an entire season's run on continuous work of a favorable character. The work actually done was not carried on continuously, and the best record made was 40,000 cu. yd. per month for two shifts for one machine. At a cost of $50 a day for two shifts this would amount to about 3 ct. per yd. for the month's work.

The machine has a reach of 210 ft. from the far side of the ditch to the near side of the waste bank. That is, all the dirt must be excavated and deposited in a space of 210 ft., making a waste bank about 20 ft. high if necessary. The bucket is remarkably well under control.

This machine was in many ways crudely built, and its excellent record is due apparently to the exceedingly simple principle of its operation, and to the economy of power, motion and time in excavating. The bucket moves on a straight line, across the excavation and onto the waste bank, and when dumped slides with great rapidity down the tightened cable to the position for digging.

With a construction including modern devices for moving on the work and the improved bucket, it seems that this should be a very important addition to the types of excavating machinery. It is fitted for digging ditches 20 to 100 ft. wide and 2 to 30 ft. deep, though its greatest economy of operation is in constructing the larger sections.

SELF-CONTAINED MACHINES

The Drag Scraper Excavator has been used with great success on the New York Barge Canal. Where canals are being dug and a large waste bank must be built, or where a heavy fill is to be made in ground which is average and has no large boulder or tree stumps, this machine is very successful. The scraper bucket is suspended by cables from the end of a long boom. Booms 90 ft. or 100 ft. long, giving a reach of 100 or 110 ft. from the center of the machine to the end of the boom, are practicable. The entire machine swings on a circular turn-

Fig. 133. Drag Scraper Excavator Used on New York Barge Canal.

table. The bucket is filled by pulling it directly toward the center of the machine by means of a cable so there is no strain on the boom except that due to its own weight and the weight of the bucket and its load. As a result the booms of this type of machine can safely be made lighter and consequently longer than is the case with the booms of dipper dredges of similar size and strength. A machine of the type illustrated (Fig. 133). used on the New York Barge Canal, has an 85 ft. boom, a reach of 96 feet and weighs 147 tons. A 2 yd. dipper is used which in operation is usually filled full and sometimes carried 4 yd. at a load. The engine is of 15 hp. capacity and the boiler 54 hp.

The machine is probably strong enough to operate a 3¼ yd. dipper. It excavated earth 90 ft. from the center of the machine on one side and deposited 100 ft. from the center on the other side. It can deposit material on banks from 20 to 35 ft. in height. A machine is usually moved forward by means of cables.

During May, 1910, the items of cost of operation were as follows:

Engineer, at $90 per month	$ 90.00
Engineer, at $95 per month	84.04
Firemen, pumpmen, watchmen and laborers at $1.75 per day	363.00
Coal, at $3 per ton	147.00
Repairs	15.82
Total	$699.86

The first cost of this machine was $10,000. The cost of operation of this machine on the New York Barge Canal was as follows:

Item	April	May	June	July	August
Fitting up	$426.80	.....	.....	.....	.....
Excavation	319.74	$684.29	$747.77	$ 850.69	$1,118.57
Repairs	.....	15.82	62.60	48.23	75.12
Interest and depreciation, 21%	175.00	175.00	175.00	175.00	175.00
Shifting on work	.....	*	.....	77.02	.....
Total	$921.54	$875.11	$985.37	$1,150.94	$1,368.69
Average cost per yd.	$0.177	$0.048	$0.0388	$0.0348	$0.0289
Yards complete during month	5,205	18,365	25,333	33,055	47.363

* Machine fell into canal.

Electrically Operated Drag Line Machines. Average cost for the season, including all charges, 4.1 ct. per yard. Two large electrically operated drag line scrapers were used on the Calumet Sag Channel near Chicago. These machines had 100 ft. steel booms and were equipped with 2½ cu. yd. scraper-buckets, and each weighed about 120 tons. The following description is reprinted from *Engineering and Contracting*, Jan. 22, 1913:

The arrangement of the operating machinery is shown in the accompanying drawing (Fig. 134). The double drum hoist is operated directly by a gear on the shaft of a 112 hp., 60-cycle, 3-phase motor, making 690 r. p. m. A 52 hp., 60-cycle, 3-phase motor, 855 r. p. m., operates the bevel swing gear as shown. The air brakes are operated through power furnished by a 25 cu. ft. motor-driven air compressor. The current is furnished by a public service company and is brought from Blue Island, several miles away, over a high tension line at 33,000 volt to a trans-

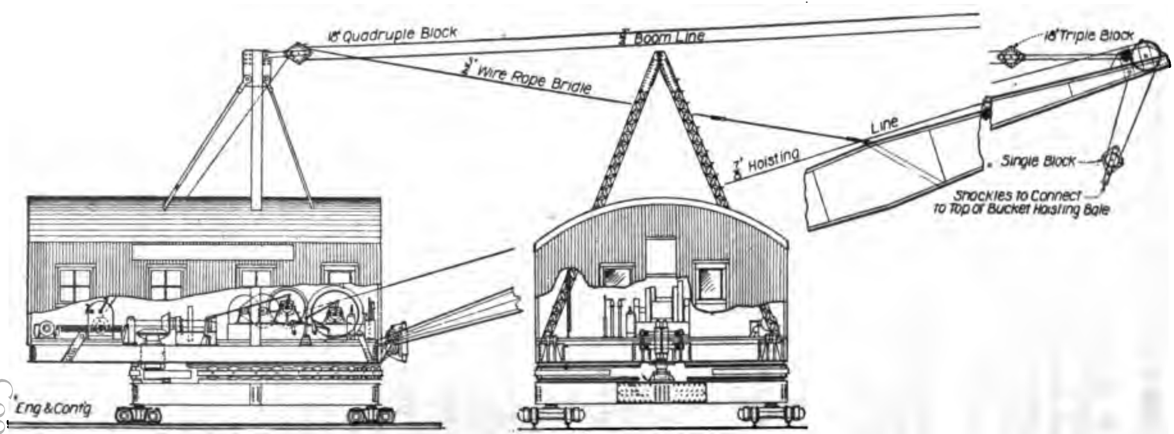


Fig. 134. Arrangement of Operating Machinery of Electrically Operated Dragline Excavator.

former house on the work where the voltage is stepped down to 2,300 volts. It is again stepped down to 440 volts through a portable transformer which is attached to the dragline machine by a cable and is pulled along on its trucks as the machine moves ahead. On the machine the current is stepped down to 110 volts for the incandescent lamps and to 35 volts for the searchlight which is placed on the front of the house and just under the boom.

The machine is operated by two men on board and two men outside for handling the track. While moving to position or commencing work one of the machines was moved 410 ft. in one day. The track sections upon which the machine runs are 15 ft. long and are built up solidly. They are built of a solid 3-in. plank bottom upon which are fastened the ties set about 8 in. apart. On top of the ties are 8 x 16 in. timbers on edge under the 90-lb. rails. The whole is bolted together and has eyebolts near the ends of the 8 x 16 in. timbers so that it can be handled by a four-way chain.

The work upon which the machines are engaged consists of about 8,000 ft. of canal section from 31 to 37 ft. deep, 36 ft. wide on the bottom and with slopes of 2 on 1. The south berm will be about 90 ft. wide or will extend 150 ft. from the center line of the canal and the north berm will be 40 ft. narrower, according to the plans. About 8 to 12 ft. of the bottom work on Section 5 will be rock and it is not yet decided by the contractor how this will be handled, though it is likely to be handled in skips by a derrick with a very long boom. The dragline machines are set on opposite banks. The one on the south will excavate half the canal section in two cuts.

That the use of electricity will be economical is illustrated by machines in California which actually used ⅕ of a K.W.H. per cubic yard of material handled. The cost of the current there was on a sliding scale ranging from ¾ to 1 ct. per kilowatt hour. On the New York Barge Canal electrical machines were used where the cost of current at about 2½ ct. per kilowatt hour was about 1 ct. per cubic yard.

The reliability of power is a most important argument in favor of the use of electricity. The uncertainty of securing fuel and water, especially in bad weather, is a source of trouble to the contractor.

The cost of hauling coal for a steam machine of this size would likely amount to $40 per day, and the coal itself (about 10 tons) would cost about $30. These items are eliminated where electricity is used, and the cost of the current is substituted.

Electric Dragline Work on the Boise Project. The following notes are from *The Excavating Engineer*, April, 1916.

In the spring of 1912 the Reclamation Service made a careful survey of the district and proposed the construction of a system of open-cut drainage ditches. This plan called for the construction of 50.4 miles of open drains varying in depth from 7 to 14 ft. and in bottom width from 5 to 12 ft. with side slopes of 1½ to 1. The system contemplated 2,000,000 cu. yd. of excavation besides many culverts and bridges, the total expenditure of which was $225,000. Actual construction was started in Nov., 1913, and completed by June 5, 1915. The excavation was done by two Bucyrus electrically operated dragline excavators mounted on caterpillars.

A third Bucyrus electric dragline, similar to the two above mentioned, was used for digging drainage ditches on the Fargo Basin of the Boise Project proper. This work was completed in April, 1915, and consisted of 275,644 cubic yards of excavation or about 5½ miles of open drains. Some of the records given later refer to this work. This work, because of softer material and less water, was comparatively easier than that on the Pioneer Irrigation District. Consequently, this must be kept in mind in reading the records of output.

Conditions existing demanded the use of electricity to operate the machines. The water throughout the district is unfit for boiler use, due to the large amount of alkaline salts which it contains. Furthermore, for a large part of the time, the machines were working in swamps where it was at times impossible to drive a loaded wagon close enough to the machines to supply them with fuel. Power was secured from a 44,000-volt transmission line that passes through the district. This voltage was reduced to 4,000 volts at a field sub-station, from which it was delivered to sub-stations at the excavators where the current was again reduced to 440 volts.

Power was purchased for one cent per K. W. hour. The average amount of power used per cubic yard of material moved was 0.9 of a kilowatt.

Each dragline had a 50 ft. boom, a 1¼ yd. bucket and weighed about 55 tons. The main machinery was driven by a motor of 50 hp. continuous and 80 hp. intermittent rating and the swinging machinery by a 25 hp. motor. The character of the material over which the excavators operated was so soft that a caterpillar mounting was chosen.

The following is the performance of machine No. 1 during August, 1915:

RECORD ON 1¼ CUBIC YARD ELECTRIC DRAGLINE EXCAVATOR BOISE PROJECT, AUGUST, 1915.

No. 1 Dragline, East Caldwell Drain

	Amount excavated		Average number of cu. yd. excavated	
	linear ft.	cu. yd.	Per hr.	Per shift
	3,150	22,617.5	185.8	1,256.5
	2,680	19,787.7	175.9	1,164.0
	2,080	16,184.3	173.6	1,135.7
Total and average..	7,910	58,589.5	178.9	1,189.6

Highest run per shift this month: 1,573 cubic yards.
Number of shifts dug: 49¼.
Excavation started August 14, 1915.

Machine Efficiency, Machine No. 1

	Hours	Per cent.
Digging	327:30	77.2
Mechanical repairs	58:30	13.8
Electrical repairs	24:30	5.8
Moving	12:45	3.0
Blasting	:45	.2
Total	424:00	100.0

The total yardage excavated by the two machines on the Pioneer District under the original contract was 1,755,238 cubic yards neat measurement. Probably 20% of the material would class as hardpan. A total of 16,200 pounds of dynamite was used in blasting. All of the material was saturated and often very soft and miry. Both excavators were operated continuously, three eight-hour shifts per day, with the exception of the month of January, 1915, when work was suspended because of deep frost and a 10-day delay on one machine in September, 1914.

The best month for one machine on the original Pioneer contract was made in March, 1915, on the Solomon Slough Drain. We give this below.

Total yardage	88,633 cu. yd.
Average per hour	155.3 cu. yd.
Average per shift	996 cu. yd.
Highest shift	1,436 cu. yd.

On the original contract from Feb., 1914, to June, 1915, inclusive the highest average per hour was 133.1 cu yd. Average number of hours actually worked per 8-hour shift was 6.13. The highest average per shift was 850 cubic yards, working an average of 6.71 hours per 8-hour shift.

As stated, the work on the Fargo Basin was somewhat easier,

and below is the average for the month of March, 1915, on the Laht and Griffith Drains.

Total yardage	84,743 cu. yd.
Average per hour	180.3 cu. yd.
Average per shift	1,176 cu. yd.
Highest run per shift	1,701 cu. yd.
Shifts worked	72

In September, 1915, on the Midway and Nampa Drains of the Pioneer District, under the supplemented contract, the following were recorded:

Total yardage	64,194 cu. yd.
Average per hour	177 cu. yd.
Average per shift	1,187 cu. yd.
Highest run per shift	1,882 cu. yd.
Shifts worked	54

Cost of Operation

The crews employed consisted generally of three men, an operator, an oiler and a laborer. The laborer, however, was only used when blasting was necessary.

Below is the unit cost of the work per cubic yard on the Pioneer Irrigation District accomplished under the original contract, exclusive of depreciation and overhead cost.

Labor:		
On excavation	$0.0105	
On repairs	.0044	
On blasting and drilling	.0012	
On moving machine	.0029	
On clearing right of way and trimming banks	.0006	
On engineering and superintendence	.0033	
Total labor cost		$0.0229
Electrical power at .01 per kw. hour	$0.0088	
Repair parts and miscellaneous supplies	.0077	
Wire rope and armored cable	.0015	
Blasting supplies	.0015	
Total unit material and supply cost		$0.0195
Electrical installation of transmission lines	.0125	
Total unit cost		$0.0549

Cost of Draglines. Draglines may be had in a wide number of sizes and capacities. They are operated by steam, electricity or internal combustion engines and are furnished on skids, traction wheels, caterpillars or trucks with or without the self-propelling feature.

The steam operated machine is the most widely used at the present time and the following prices are for that type of machine.

A steam operated dragline mounted on skids, with a 45-ft. boom and 1½-cu. yd. bucket, weighs 39 tons and costs $20,800

Fig. 134A. Steam Operated Dragline Mounted on Caterpillars Building a Levee in Missouri. Length of Boom, 45 ft., Size of Bucket 1½ cu. yd.

f. o. b. factory. This same size machine mounted on caterpillars weighs 60 tons and costs $29,000.

A dragline mounted on skids, with a 60-ft. boom and 2-cu. yd.

Fig. 134B. Steam Operated Dragline with a 125-ft. Boom and 5-cu. yd. Bucket on Levee Enlargement Work on the Mississippi River.

bucket, weighs 62 tons and costs $26,700, mounted on caterpillars the machine weighs 89 tons and costs $38,300.

A dragline mounted on skids, with a 100-ft. boom and 3½-cu.

yd. bucket, weighs 145 tons and costs $46,900, mounted on self-propelling trucks the machine weighs 166 tons and costs $56,800.

A dragline mounted on self-propelling trucks, equipped with a 125-ft. boom and 4-cu. yd bucket, weighs 210 tons and costs $71,300.

Various combinations of boom lengths and bucket capacities may be had. For certain work, such as levee building, it is very often advantageous to have a machine with a longer boom and a bucket of smaller capacity. The manufacturer is prepared to meet special conditions by designing machines accordingly.

Electrically operated machines are economical where no great distances are to be moved and, of course, where electric power suitable for the operation of the machine is available.

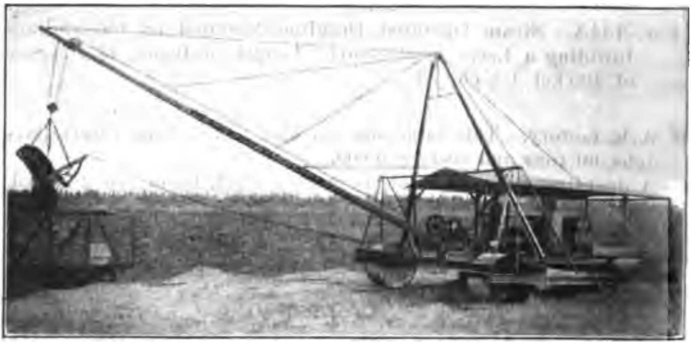


Fig. 135. At Work in a Gravel Pit.

Gasoline or kerosene engine power may be applied to the smaller sizes of machines; two machines being described below.

A gasoline engine operated drag line excavator (Fig. 135) weighs approximately 32,000 lb. for shipment and costs $6,000 complete The engine is 40 hp. for either gasoline or kerosene. It is equipped with a ⅝ cu. yd. bucket.

This machine will, on open work, dig and place tile in the trench, and then backfill the trench. In this kind of work, two men are necessary for the operation of the machine; one man for the actual operation and one to do the incidental work around the machine during the operation. The machine may also be used in ditch cleaning and repairing, and other work where a light drag scraper machine can be used to advantage.

Gasoline Dragline Excavator having a 30-ft. boom, operates a ¾-yd. bucket and is furnished with caterpillar traction. This

iachine is operated by a marine type gasoline motor, has an stimated capacity of 300 to 600 cu. yd. in 10 hr. depending n the material and a traction speed of from ½ to 1¼ miles er hr. It uses from 35 to 45 gal. of gasoline, kerosene or disillate in a 10 hr. day. The approximate shipping weight of he machine is 38,000 lb. and it costs $9,530 f. o. b. factory without he bucket.

The following cost data of a traveling excavator appeared in n article by Mr. W. W. Patch in *Engineering Record*, Dec. 12, 914.

When operating under the most favorable conditions this mahine, with a crew of four men, excavated 400 cu. yd. in a day f 8 hr. While for a period of seven months the average perormance has been at the rate of 40 cu. yd. per hour, even when ime lost on account of repairs and moving from place to place s included. If blasting is required, or if the ground is so soft s to require planking beneath the wheels of the machine, then he crew is increased to a total of six men.

Costs of Operating Traveling Excavator in Southern Oregon for Seven Months, April to October, 1913.

Item	Cost	Cost per cu. yd.
Labor, men	$2,670.38	$0.0476
Labor, horses	499.30	.0089
Explosives	324.97	.0058
Fuel, gasoline	290.03	.0052
Supplies (grease, oil, lumber, etc.)	524.75	.0094
Depreciation, machine	1,194.00	.0213
General expenses	712.15	.0127
Miscellaneous	99.00	.0018
Repairs	340.65	.0061
Total	$6,655.23	$0.1188

The work comprised deepening an old ditch which carried drainage water constantly. The old section was about 2 ft. deep, 4 ft. wide, and had 1.5 to 1 side slopes. The new section was 5 ft. deep, 5 ft. wide at the bottom and had 1.5 to 1 side slopes. The ditch was about 4 mi. long, and for approximately one-half of its length the bottom 2 ft. was in indurated materials which required blasting before it could be excavated.

The crew comprised from 4 to 6 men and 2 horses at the following wages: Machine operator, $130 per month; gas-engine man, $80 per month; powder-man, $3 per day; 2 laborers, each $2.48 per day; 2 horses, each $1.25 per day. A day's work comprised 8 hr. on the job. The total material moved was 56,017 cu. yd. or approximately 40 cu. yd. per hour.

SECTION 32

DRAWING BOARDS

Drawing boards of thoroughly seasoned, selected narrow strips of white pine, and either finished natural or with a light coat of shellac, cost as follows:

One face for drawing	12 x 17 in.	$1.25
One face for drawing	16 x 21 in.	2.00
One face for drawing	20 x 26 in.	2.80
Both faces for drawing	12 x 17 in.	1.25
Both faces for drawing	16 x 21 in.	2.00
Both faces for drawing	20 x 26 in.	2.80
Both faces for drawing	23 x 31 in.	4.00
Both faces for drawing	27 x 34 in.	5.50
Both faces for drawing	31 x 42 in.	7.50

Drawing boards of white pine, with hardwood ledges attached by screws, arranged to allow for contraction and expansion:

One face for drawing	31 x 42 in.	9.80
One face for drawing	33 x 55 in.	15.00
One face for drawing	36 x 60 in.	17.50

Extra large drawing boards of pine:

36 x 72 in.	$ 28.00
36 x 84 in.	32.00
42 x 60 in.	27.00
42 x 72 in.	32.00
42 x 84 in.	37.00
42 x 96 in.	48.00
48 x 72 in.	42.00
48 x 96 in.	64.00
48 x 120 in.	80.00
54 x 96 in.	72.00
54 x 120 in.	90.00
60 x 96 in.	83.00
60 x 120 in.	103.00

Trestles and horses for drawing boards. Wooden horses, light construction, 37 in. high, 35 in. long, per pair, $5.60.

Ditto, fine quality, 37 in. high, 35 in. long, per pair, $9.75.

Ditto, fine quality, with removable sloping ledges, 37 in. high, 35 in. long, per pair, $10.50.

Adjustable wooden horses, best workmanship, 36 in. long, adjustable for height from 37 in. to 47 in. on level or slope, per pair, $13.20.

Adjustable drawing table with iron supports:

Board, 31 x 42 in. each	$60.00
Board, 33 x 55 in. each	66.00
Board, 36 x 60 in. each	69.00
Board, 42 x 72 in. each	83.00

SECTION 33

DREDGES

There are four types of dredges: (1) The dipper dredge; (2) the grapple dredge; (3) the bucket elevator dredge; (4) the hydraulic dredge. For harbor work or where the water is rough the scow containing the machinery also has pockets for the material, which it conveys to sea or some other dumping place. This is called a hopper dredge.

DIPPER DREDGES

A dipper dredge is really a long-handled steam shovel mounted on a scow. The dippers range in size from 1/3 to 15 cu. yds. This type of dredge is adapted to work in all kinds of materials.

Mr. Gillette, in "Earthwork," describes a home-made dipper dredge, the cost of which was as follows:

1	Hoisting engine and boiler (single drum, dbl. cyl., 8 hp., 4¾ x 6 in.; weight 3,500 lb.)	$ 500.00
2	Scows, 3,200 ft. B. M. (6 x 34 ft.)	150.00
10	Sheaves, 6 in.	20.00
120	Ft. 7/16 in. hoisting chain, 250 lb., @ 8 ct	20.00
160	Ft. ¾ in. iron, 250 lb., @ 4 ct.	10.00
1	Dipper, 1/3 yd., 400 lb., @ 10 ct.	40.00
40	Ft. cast iron rack, 200 lb., @ 10 ct.	20.00
1	Turntable plate and rim, 100 lb., @ 10 ct.	10.00
100	Bolts, ¾ x 12 in., 200 lb., @ 5 ct.	10.00
1,000	Ft. B. M. yellow pine	30.00
	Labor and sundries	190.00
		$1,000.00

This dredge can be loaded on two flat cars or four ordinary wagons. The crew consists of three men and the total cost of operation is about $8.00 per day. In digging a trench 18 ft. wide by 12 ft. deep the average capacity in 10 hours is 60 yards of hardpan or 175 yards of river gravel.

In *Engineering News* of October 30, 1902, is described a dipper dredge with a 2½ cu. yd. bucket which excavated in clay 20 ft. below the water, depositing the material in two scows, each having a drop pocket of 140 cu. yd. A tug boat towed the scow containing material to the dumping ground. The total cost of the outfit was $43,000. Six per cent interest plus 6 per

cent depreciation over 100 working days gives a cost of $51.60 per day. The usual rental of such a plant is $100.00 per day. The daily wages and coal bill average about $30.00. The average output in 10 hours was 745 cu. yd. at a total cost of 11c per cu. yd.

Land Dredges of the dipper type are made by one manufacturer in two designs; the walking and track type. They may also be adapted for floating work.

These dredges are adapted to a very wide range of work, but are more frequently used in the construction of drainage

Fig. 136. Dipper Dredge — Walking Type.

and irrigation ditches having approximate dimensions of from 6 to 50 ft. top width, 4 to 20 ft. in depth, constructing the required slope of bank, ranging from ½ to 1½ ft. back to 1 ft. in perpendicular, also establishing a berm width ranging from 6 to 10 ft.

They are well adapted to the recleaning of old drainage or irrigation canals where small yardage is encountered, necessitating the installation of only such machinery as can be moved on to the work at a small first cost, and can be operated rapidly at a minimum of cost for labor and supplies.

When not on work incident to the construction of new ditches or the recleaning of old structures, they can be adapted to handling gravel from bank or pit into auto trucks or gondola cars when used in connection with general construction.

The yardage handled by this type of equipment depends quite largely upon the class and nature of the soil being handled and upon the skill and familiarity of the principal operator with his equipment. Under normal conditions, the ½ yd. equipment will handle from 400 to 800 yd. of earth per 10 hr. shift, while the 1 yd. capacity will handle from 600 to 1,100 yd. for the same length of time. While an experienced operator who is willing to make use of his skill can attain the best results, it is not essential to provide such a man, as one with average mentality and willingness to do the thing as directed can attain a

Fig. 137. Dipper Dredge — Track Type.

sufficient knowledge of this equipment to operate it safely and with satisfactory results within a period of from two to six days. The manufacturer states that the mechanics furnished to erect the dredges in nearly every case instruct new men in the operation.

The walking and floating types of land dredge are frequently and generally handled by a chief operator and helper, the helper being the understudy of the operator. He does lubricating, provides water for the cooling system of the oil engine, and many small jobs incident to the operation. The track type dredge requires a principal operator and a man to lay track on either side of the dredge under favorable conditions, and additional men to lay track when soft earth is encountered or difficulties

incident to new work through timbered areas. When used in the work of loading trucks or cars the principal operator is the only one required.

The costs of supplies and operation depend largely upon those of labor, fuel and lubricating oil, cable, and repairs, in the locality where the work is being done. Under reasonably favorable conditions these vary in the case of the walking type of dredge from $15 to $25 per day; in the case of the track type from $18 to $30 per day.

The approximate cost of these dredges is as follows:

WALKING DREDGE

Span in ft.	Capacity in yd.	H.P.	Boom in ft.	Approximate wt. in lb.	Price f. o. b. Michigan
14	½	20	26	38,000	$6,900
17	½	20	30	40,000	7,100
17	1	30	30	42,000	8,900
23	1	30	36	65,000	9,000
28	1	30	40	69,000	9,200
33	1	30	40	75,000	9,400
38	1	30	45	78,500	9,600

TRACK TYPE DREDGE

Span in ft.	Capacity in yd.	H.P.	Boom in ft.	Approximate wt. in lb.	Price f. o. b. Michigan
14	½	20	26	33,000	$4,700
18	½	20	26	35,000	4,800
22	1	30	26 or 30	46,000	6,400
26–29	1	30	38	52,000	6,700
32–35	1	30	40	56,000	6,950
37–40	1	30	40	60,000	7,100
42–45	1	30	45	64,000	7,300
50–52	1	35	52	68,000	8,500
60	1	45	52	84,000	9,100

Dredges of this make are operated by oil engines of either the single cylinder or double cylinder opposed type, using for fuel either gasoline, kerosene or distillate. These engines are mounted on a structural base, which is in turn mounted upon skids, these skids carrying as a separate unit the engine fuel and cooling tanks. In this manner the power plant is intact. The engine is controlled by the operator from his position in the front of the dredge.

The dredges are of all steel construction, and are designed to dismantle into sections for easy transportation, the entire equipment being divided into from ten to fifteen loads for the ordinary wagon or truck.

Methods and Costs of Dredge Excavation of Drainage Ditches. The following notes by Mr. D. L. Yarnell are from Bulletin No. 300, Office of Public Roads and Rural Engineering, on "Excavat-

ing Machinery used in Land Drainage." The cost figures are as of 1915.

The cost of dredges advances rapidly as the size and capacity are increased. Dredges of the same rated capacity also vary somewhat in cost with the different manufacturers. All of the machinery is usually made at the shops of the manufacturer. The material for the hulls may also be supplied by the manufacturer, but usually the purchaser obtains lumber in the open market and builds the hull in the field. The cost of hauling the material and machinery from the railroad to the place of erection, the local price of labor, and the conveniences for housing and feeding the workmen are factors which will enter into the cost of a machine of any type. It requires at least two cars to transport the material for a small dipper dredge, while for a machine of large size from four to six cars are required.

The following table gives the approximate costs of the various sizes of dredges ready for operation, though these would be largely affected by the difficulties and expense of transporting the material and assembling the machine:

APROXIMATE COSTS OF DIPPER DREDGES

Size	Cost of machinery	Cost of wood hull	Total
¾-yard	$ 3,700	$1,800	$ 5,500
1-yard	5,400	2,200	7,600
1¼-yard	6,100	2,250	8,350
1½-yard	7,100	4,500	11,600
2½-yard	14,000	9,000	23,000

It requires practically a month for ten men to erect a 1-yard dredge, six weeks to erect a 1½-yard dredge or 1¾-yard dredge, and eight weeks to construct a 2-yard or 2½-yard machine. It requires less than one-half the time given above to dismantle a machine. A 1-yard dredge which cost $8,000 was shipped about 400 miles and hauled by wagon 18 miles. The dismantling cost about $490; the freight charges were about $700; hauling, $360; and rebuilding about $670. These costs are fairly representative for this size of machine.

Method of Operating. With a floating dredge the construction should, where practicable, begin at the upper end of the ditch and proceed downstream. Sometimes it is not feasible to transport the machinery and material to the upper end of the ditch and the dredge must then work upstream. This is undesirable, unless the fall be slight, since in working upstream dams must be built behind the boat to maintain the necessary water level. In working downstream the ditch remains full and the dredge, floating high, can dig a much narrower bottom than if working up-

stream in shallow water. Moreover, when floating low, the dipper may not properly clear the spoil bank. Again, in working downstream, any material dropping from the dipper into the ditch will be taken out in the next shovelful; whereas if working upstream any material dropped or any silt washed behind the dredge is left to settle in the bottom of the ditch. If work is begun on the natural ground surface a pit must be dug to launch the boat; or if in a stream, it may be necessary to build a temporary dam in the channel to raise the water high enough to float the boat. The depth of water required varies from 2 ft. upward, depending on the size of machine.

The floating dipper dredge moves itself ahead by means of the dipper. The spuds are first loosened from their bearings and the dipper is run ahead of the machine and rested on the natural ground surface in front of the ditch. The spuds are then raised and the engines operating the backing drum are started; the dredge, being free, is thus pulled ahead. The spuds are then lowered and excavation continued.

In timbered country the right of way must be cleared. In many cases the timber cut will supply sufficient fuel for the dredge. It is poor policy to fell the trees and leave them on the ground to be removed by the dredge. The stumps should always be shattered with dynamite, as the strain on the machinery is thus rendered much less and the life of the dredge increased.

An engineer, a craneman, a fireman, and a deckhand are required to operate a dipper dredge. The output, loss of time due to breakdowns, and the cost of repairs, depend almost wholly upon their skill and efficiency. The engineer should be an all-around mechanic as well as experienced in dredging.

The amount of fuel consumed depends upon the size and type of boiler used, and upon the burning and heating qualities of the fuel. A very great saving can be effected by covering the boiler with an asbestos coat. Ordinarily, about 25 lb. of coal per horsepower-hour are consumed on dredges. The cost of repairs depends largely upon the operator; a careless operator will cause many unnecessary breakdowns. It is not only the high cost of repairs for machinery but also the time lost which aids in increasing the actual cost of the output. It is a well-established fact that it is not the initial cost of a dredge or of any machine, but the operating and overhead expenses, that reduce the profits.

Cost of Operation. The cost of dredge work depends upon a number of factors. The locality of the work, the kind of soil, repairs, delays, labor, etc., greatly influence the actual cost of any work. If the water level can naturally be maintained within a foot or so of the surface of the ground, the cost of excavation

can be reduced very low with this type of machine. The data given in the following pages were obtained from the actual cost records of the various projects. Unfortunately, the figures are not always strictly comparable, one project with another, owing to variations in the items of cost included. Unless otherwise stated, interest is taken at 6% and depreciation at 35% per annum on the cost of the dredging outfit. Interest and depreciation are, however, charged only for the interval of time upon which the unit cost is based. This is not strictly correct, as a certain amount of time consumed in getting the machine on and off the work should be charged to each project. In most cases it was impossible to ascertain the time that should be charged to moving, building, etc., and therefore the item has been ignored in all cases, for the sake of uniformity. On some projects figures for operation over an extended period were not obtainable. In such cases the unit cost is based upon the daily cost of operation and the average amount of ditch dug per day, no allowance being made for interest and depreciation.

In the construction of a ditch in North Carolina a new 1¼-yard dipper dredge was employed. This dredge had a 5 x 20 x 70-ft. hull and was equipped with 8⅜ x 10-in double-cylinder hoisting engines; 7 x 7-in double cylinder, reversible swinging engines; a 50-hp. Scotch marine return-flue boiler; a 1¼-yard dipper, 31-ft. dipper handle, and 45-ft. boom. The spuds were convertible to bank or vertical and were operated by the hoisting engines. The cost of this dredge, erected, was $10,342.19. The dredge was operated continuously, each shift working 11 hours per day. The men were paid at the following rates per month: Superintendent in charge, $110; engineers, $100; cranemen, $60; firemen, $48; deck hands, $36. The men furnished their own subsistence. The ditch was 9½ miles long and ranged from 22 to 30 ft. wide on top and from 8 to 10 ft. deep; it had side slopes of ½ to 1 and a berm 8 ft. wide. The water level was easily maintained near the ground surface. Very little right-of-way clearing was required. In the construction of this ditch the dredge excavated 350,720 cu. yd. of earth. One year was required for the dredge to complete this work. The following cost data were taken from the records of the drainage district which owned and operated the dredge:

Cost of operation, including labor and fuel	$15,889.01
Repairs	1,948 24
Interest and depreciation	4,240.22
Total	$22,077.47

Cost per cubic yard, $0.0629.

A new dredge of the same size and type as the one just

described was used in the excavation of a drainage ditch in the same locality as the foregoing project. The ditch followed an old creek channel for the greater part of its length. The cost of the dredge, erected, was $9,365.34. It was operated in one shift of 11 hours; the actual time of operation was not recorded. The crew and the rates of pay were the same as in the foregoing example. The ditch was 3¾ miles long and ranged in top width from 22 to 26 ft. and in depth from 6 to 10 ft. The side slopes were ½ to 1; the berm was 8 ft. wide. The dredge worked down-stream and the water level was easily held near the ground surface. Practically no right-of-way clearing was done. The material excavated was a loam top soil underlain by stiff clay; very little rock was encountered. The cost of the work was considerably affected by the expense ($1,459) of passing three bridges. The total amount excavated in a period of about 10 months was 121,290 cu. yd. The dredge was owned and operated by the drainage district. The following costs were recorded:

Cost of operation, including labor and fuel	$ 5,921.05
Repairs	1,028.73
Incidentals	117.95
Interest and depreciation	3,199.80
Total	$10,267.53
Cost per cubic yard, $0.0847.	

A dipper dredge with a 5½ x 16 x 60-ft. hull, 7 x 8-in. double-cylinder hoisting engines, friction swing, 1-yard dipper, 35-ft. boom, and telescopic bank spuds was used in the construction of about 5 miles of ditch in western North Carolina. No reliable information was available as to the amount of material moved; but the following figures as to the cost of installing the dredge are of interest:

Hull: Labor and material	$1,803.23
Machinery:	
Material	4,800.00
Freight	379.10
Drayage	72.60
Installing	310.60
Extra equipment (forge tools, etc.)	80.00
Lighting equipment (engine and dynamo and wiring)	207.00
Total	$7,652.53

In Colorado, a dipper dredge having a 24 x 75-ft. hull, 1½-yd. dipper, and 50-ft. boom, was used in cleaning out and enlarging about 20 miles of canal. The equipment, complete, including cook and bunk boats, cost $16,500. Two shifts of 11 hours each were run. During the year for which the data are given the dredge was actually in operation but 187 days, or 58% of the

total working days. The following crew were paid the given rates per month, including board: Head runner, $120; 1 runner, $110; 2 cranemen at $55; 2 firemen at $45; 2 deckhands at $40; 1 teamster, $40; 1 cook, $50. No right-of-way clearing was required. The water for the boiler was taken from the canal, and as a result considerable trouble was experienced from mud and scale. The cost data below are based on the amount of material moved from inside the grade stakes during the year, amounting to 394,387 cu. yd. It was estimated that an excess of 25% was actually moved. The following was the cost of the work for one year:

Operation:	
Labor operating dredge	$ 6,243.70
Coal, including freight, 1,276.65 tons, at $2.35	3,000.13
Hauling coal, 1,276.65 tons, at 82½ ct.	1,053.24
Oil, waste, and miscellaneous supplies	692.80
Cost of controlling water to float dredge	369.24
Repairs, labor, and material	3,894.67
Removing and replacing bridges	837.78
Interest and depreciation	6,765.00
Total	$22,856.56
Cost per cubic yard, $0.058.	
Miscellaneous expenses:	
Engineering and supervision	$ 1,856.10
Building up ditch bank and making road on top	4,721.75
Right of way and legal expenses	190.42
Total	$ 6,768.27

The cost of the dredging outfit was as follows:

Hull:	
Material	$ 1,960.83
Labor, including hauling	1,959.99
Machinery:	
Cost, including freight	9,997.72
Hauling and installing	817.55
Cook and bunk boats:	
Material	663.90
Labor	453.66
Equipment	646.35
Total	$16,500.00

In connection with a drainage project in southwest Louisiana a steam-operated, floating dipper dredge, equipped with a 1-yd. dipper, 40-ft. boom, and convertible power spuds was employed in the excavation of about 10 miles of ditch which varied in width from 18 to 50 ft. and depth from 4 to 6 ft.; 15-ft. berms were specified. The cost of the dredge on the work is said to have been $10,000. Two shifts of 10 hours each were run, but the actual number of days of operation was not recorded.

The crew and monthly rates of pay, including subsistence, were as follows: Two runners, at $100; 2 cranemen, at $60; 2 firemen, at $60; 1 deckhand, $40; 1 cook, $30. The material excavated was a hard, stiff clay. The total amount excavated in about 8 months was 147,000 cu. yd. The average cost, per month, of operation was as follows:

Labor	$ 510
Board	100
Coal	262
Repairs	200
Oil and supplies	50
Interest and depreciation	342
Total	$1,464

Cost per cubic yard, $0.0796.

On another project in southern Louisiana there was employed a floating dipper dredge with a 5 x 22 x 73-ft. hull; 8 x 10-in. double-cylinder hoisting engine; 6 x 8-in., double-cylinder reversible swinging engines; 1¼-yd. dipper, and 40-ft. boom. The machine was equipped with bank spuds. The cost of the dredge, ready to operate, was $13,000. The ditches averaged about 30 ft. wide and were from 5 to 6 ft. deep. The land was nearly level and the water surface was easily kept within a foot of the ground surface. The material was a top muck underlain by an alluvial mud which was hardly solid enough to hold its shape when dropped from the dipper. There were few submerged logs or stumps. The dredge was operated the year around for two years. No record was kept of the actual time of operation. The average output per shift (12 hours) on a 30-ft. ditch 5 ft. deep was 1,200 cu. yd., at a cost as follows:

Labor (4 men)	$10.50
Fuel, 6 bbl. oil, at $1.75	10.50
Repairs, oil, and grease	5.50
Total	$26.50

Cost per cu. yd., exclusive of interest and depreciation, $0.0221.

In the same general locality as the foregoing case, and under the same soil conditions, a 1-yd. dredge which was, except in respect to capacity, equipped similarly to the above-described machine, was operated in the construction of ditches which averaged 30 ft. wide and 5 ft. deep. The cost of the dredge, erected, was $11,000. The average output per 12-hour shift during a 2-years' run was 1,000 cu. yd. The cost per shift was as follows:

Labor (4 men)	$10.00
Fuel, 5 bbl. oil, at $1.75	8.75
Repairs, oil, and grease	5.50
Total	$24.25

Cost per cu. yd., exclusive of interest and depreciation, $0.0242.

In another drainage project in southern Louisiana several ditches, each three miles long, were constructed by a dipper dredge installed on a 5½ x 18 x 70-ft. hull. The power was obtained from a 60-hp. internal-combustion engine. The dredge had a 1¼-yd. dipper, 40-ft. boom, and convertible power spuds. The total cost of the outfit, including house-boats and small towboats, was $12,000. Two shifts of 10 hours each were run for 26 days in each month. The crew were furnished subsistence, and each shift consisted of: One runner, at $125; 1 craneman, at $65; and 1 engine tender, at $40 per month. One cook, at $35, and one general utility man, at $60, were also employed, making a total labor cost of $555 per month. The average dimensions of the ditch were: Top width, 25 ft.; bottom width, 18 ft.; and depth, 8 ft. The ground was nearly level and the water stood about 3 ft. below the ground surface. The excavated material was stiff sandy clay. About 3.4 miles of the work consisted in cleaning the old channel, which required frequent moving and gave small yardage. The total excavation in five months was about 216,000 cu. yd. The cost was as follows:

Labor and board	$3,555
Fuel and oil	2,300
Repairs	980
Interest and depreciation	2,050
Total	$8,885

Cost per cubic yard, $0.411.

A steam operated floating dipper dredge, mounted on a 5 x 15 x 60-ft. hull and equipped with a 1-yd. dipper, 38-ft. boom, and inclined telescopic bank spuds, was used in the excavation of about 10¾ miles of ditch in North Carolina. The cost of the dredge is stated to have been $6,613.82. One shift of 10 hr. per day was run. The actual number of days of operation was not recorded. The crew and rates of pay were as follows: One engineer, $125 per mo.; 1 craneman, $2.00 per day; 1 fireman, $1.25 per day; 1 watchman, $1.50 per day; the crew furnished their own subsistence. The ditch was about 18 ft. in top width, 12 ft. deep, and had ½ to 1 slopes. It followed an old creek bed for a large part of the distance. The material excavated was a clay though some rock was encountered. Based upon the given dimensions of the ditch, the total excavation amounted to 295,000 cu. yd. Eighteen months were required to complete the work. The cost was as follows:

Operation:	
Labor	$ 6,310.94
Fuel	2,210.30

Repairs:	
Labor	1,380.12
Material	1,136.71
Interest and depreciation	4,067.00
Total	$15,105.07
Cost per cubic yard, $0.0512.	

Miscellaneous expenses:	
Engineering	164.83
Clearing right of way	282.70
Rebuilding bridges	104.96
Incidentals	48.77
Administration	618.00
Total	$ 1,219.26

Some Costs of Dredgework on the Los Angeles Aqueduct. The following costs of dredging are taken from the monthly report for February, 1911, on a section of the Los Angeles aqueduct through the Owens Valley. The dredge consists of a scow on which is mounted a No. 60 Marion electric shovel with a 1½-cu. yd. dipper. The cost of the dredge was $19,897, and it was built according to the specifications of the aqueduct engineers. The yardage is based upon the theoretical section of the aqueduct, or 14.81 cu. yd. per lineal foot. This is exceeded to a small extent by excess cutting. The following are the data for February:

	Teams and and men	Operation	Renewals and rep.	Misc.	Totals
Men, No. of days	10	205	241	3	459
Live stock, No. of days	....	56	12	....	......
Lineal feet	....	2,625	......	....	......
Cubic yards	....	38,876	......	....	......
Labor costs	$34.29	$ 727.39	$ 838.81	$17.85	$1,618.34
Live stock costs	....	50.40	10.80	....	61.20
Cost materials and supplies	....	1.75	120.32	....	122.07
Power cost	....	408.51	9.79	....	418.30
Freight cost	....	.35	24.06	....	24.41
Total costs	$34.29	$1,188.40	$1,003.78	$17.85	$2,244.32
Unit cost per cu. yd.	$0.0001	$0.0306	$0.0258	....	$0.0565

The unit cost per cubic yard for the month figures 5.65 cents, but the unit cost given for the work of the dredge to date is 6.7 cents.

Grapple Dredge. Grapple or grab bucket dredges are also known as clamshell or orange peel dredges, according to the type of bucket used in excavating. They are adapted to work in very deep water or in confined places, such as caissons.

In *Engineering News*, February 2, 1899, an Osgood 10-cu. yd clamshell dredge is described. The crew consisted of ten men, and five tons of coal were consumed in ten hours. The machine

had a capacity of one bucket load per minute and averaged about 400 cu. yd. per day.

The table on pages 296–299 has been compiled from the report of Gen. Bixby, Chief of Engineers of U. S. A., for the fiscal year of the U. S. Government ending June 30, 1911, and contains some important data. The column headed "Total Cost of Dredging" is understood to include cost of repairs, but not interest and depreciation. The oldest of these dredges seems to have been built in 1869, which would make its age at the time of the report 42 years. It is hardly safe, however, to consider this the standard age for computing depreciation. At the age of 30 a dredge is either so antiquated as to make repairs very heavy, or so out of date as to make it uneconomical to operate. Therefore, fixing 30 years as the life, which is more than that of the average locomotive in the United States, and allowing interest at 6%, the annual interest and depreciation on the total cost of the dredges would be $82,061, or about 2c per cu. yd. in addition to the average figure of 13.6c given in the table.

A clam shell dredge, Delta (Fig. 138), was used by the California Development Co. from November, 1906, to 1912 in places where it was necessary to build up levees to greater heights than could be reached by the dipper dredges. The following description is compiled from a paper by Mr. H. T. Corry, Trans. Am. Soc. C. E., November, 1912:

The dredge had a hull 120 ft. long, 54 ft. wide, and 11 ft. deep, and was equipped with a clamshell bucket mounted on a 150-ft. boom. The machinery comprised a 150 hp. internally fired, circular, fire-tube boiler, and a 20 x 24-in. engine on each side. Work on the hull was started May 1, the hull launched August 15, and the machinery in place at the end of October. The total cost of the dredge was $80,000, including $34,000 for machinery f. o. b. San Francisco. The weight of the craft was 850 tons.

Operatives:
- 1 captain at $125 to $150 per month and board.
- 3 levermen at $85 per month and board.
- 2 firemen at $60 per month and board.
- 2 deckhands at $50 per month and board.
- 1 cook at $50 per month and board.
- 1 blacksmith at $90 per month and board.
- 1 roustabout at $40 per month and board.

Three shifts were worked, making a total of 22 hours actual work per day. The average time in operation was 28 days per month. In good ground, with side swings averaging 70 degrees on each side, the time per bucketful was 40 seconds. The quan-

Class C.— Bucket

Dredge	When built Year	Contract cost and outfit Dollars	Dimensions of hull Length Beam Depth Feet	Bucket Type	Bucket Capacity C.Y.D.	Length of Boom	Dimensions of main hoisting engine cylinders Inches	No
Addison	'80	14,000	75x30x7	D	1½	31	9x18	1
Alabama	'91	22,300	80x38x6	CB	5-c. f.	None	10x14	1
Albany	'08	11,731	70x30x5	OP	1	60	8¼x10	1
Attalla	'02	17,000	75x26x6	TD	1¼	28	8¼x10	1
Autauga	'02	13,440	75x26x6	TD	1½	30	8x10	1
Carrollton	'01	22,272	80x30x7	D	2½	40	10x14	1
Frankfort	'08	10,193	72x19x5	D	¾	27	8x10	1
Green River	'96	4,094	112x31x4	D	1¼	50	8x12	1
Kentucky	'00	34,300	100x34x7	D	2–4	45	12x16	1
Kwasind	'99	11,000	80x28x7	D	1½	38	9x10	1
Sapelo	'94	12,000	85x31x5	OP	¾	56	7x10	1
Tennessee	'10	37,513	100x34x7	D	1½–2	45	10x14	1
Upatoi	'01	15,718	85x30x6	D	2	35	10½x12	2
Wolf	'97	8,000	80x28x5	D	1	40	9½x10	1
No. 1 D. B.	'08	8,800	65x27x6	C	1½	43	10x12	1
Dredge No. 1	'03	18,950	80x30x7	D	1½	45	8x12	1
No. 19	'06	4,500	76x25x7	C	1	45	8¼x10	1
Totals		$265,811						
Ajax	'76	11,300	73x26x6	D	1½	30	8x18	1
Algoma	'72	29,500	79x30x7	D	2½	Mast	12x14	1
Apache	'95	15,255	80x30x8	D	2½	34	10x12	1
Appleton	'76	18,000	90x32x7	SD	2¼	39	12x36	1
Farquhar Col.	'69	15,500	76x24x6	D	2	40	10¾x12	1
Frontenac	'91	14,650	76x26x7	D	1½	26	8¼x10	1
Maumee	'94	30,000	100x36x11	D	3½	42	14x20	2
Omro	'78	5,500	100x30x6	G	2¼	60	8x12	1
Oshkosh	'06	39,529	75x31x6	CB	5-c. f.	None	9x12	1
Ottertail	'82	12,600	75x24x6	SB	1½	28	8x16	1
Phoenix	'85	19,525	80x30x8	D	2½	34	12x18	1
Vulcan	'83	19,450	80x30x8	D	2½	34	12x18	1
Dredge No. 2	'82	15,500	80x30x7	BD	1¼	34	12x14	1
Totals		$241,309						
Ajax	'84	16,500	82x33x10	CS	5	48	18x24	1
Cheraw	'06	45,500	150x29x8	D	1¾	49	16½x18	2
Hercules	'07	64,646	100x38x11	CS	7	55	18x24	1
Scuppernong	'04	10,300	78x32x7	CS	2½	43	7x12	1
Derrick A	'07	6,000	80x28x4	OP	1¼	45	10x13	1
Bank Derrick No. 1	'10	4,487	33x8 car	Gb	1	45	8x12	1
Bank Derrick No. 2	'10	2,787	33x8-car	OP	¾	45	8¼x10	1
Totals		$150,120						
Cascade	'06	6,056	60x30x5	OP	1	52	10x12	1
Champoeg	'04	20,200	80x30x5	D	1	40	8x12	1
Cowlitz	'95	4,750	78x34x6	CS	1½	60	10x12	1
Totals		$31,006						
Casey	'07	15,132	86x28x7	CS	2	42	11x18	1
Louisville	'86	25,000	67x38x6	D	2	30	12x14	1
Malta	'88	17,000	70x31x7	CB	3-c. f.	None	10x16	1
Ohio	'73	35,000	110x32x7	D	2 7/10	24	12x15	1
Oswego	'83	35,000	92x32x6	D	2 7/10	24	12x15	1
Totals		$127,132						
Hellgate	'69	25,000	10x35x12	CS	6	50	18½x24	1
Dredge No. 1	'03	17,565	85x32x6	D	2⅛	40	11x14	2
Dredge No. 2	'05	21,600	87x30x5	D	1¾	35	10x14	2
Totals		$64,165						
Grand totals		$879,543						

and Dipper Dredges.

Type boilers	Diameter in.	Length ft.	hp.	Steam pressure lb.	Crew men	Dredging capacity per hr. c.yd.	Character of dredged material	Material dredged during year 1910–11 Yd.	Total cost of dredging Dollars	Total cost per cu. yd. Ct.	Cost of repairs $
L	54	15½	60	90	6	24	G, Sd, St.......*	15,306	3,721	24.3	115
M	60	17	40	90	7	213	SM, G..........*	137,088	6,888	5 0	1,921
U	50	10	30	100	7	50	BR ....*	18,531	4,433	23.9	342
I	78	12½	60	160	7	60	Sd, G, BR.....*	12,000	4,806	40.5	232
L	48	14½	45	100	9	120	Sd, G, Ml......*	25,464	2,895	11.4	499
T	54	16	70	110	9	90	Sd, G, Md.....†	40,610	4,168	10.3	438
FbT	50	15	40	125	9	50	Sd, G, Md.....†	37,815	7,139	18 9	282
L	48	14	61	160	8	50	Md, L, Sd, St.*	36,118	4,736	13.1	340
L	66	20	100	100	10	175	LG ....†	292,800	14,617	5.0	1,382
L	42	15	40	120	8	87	HP, R.........†	40,465	5,926	14.8	5,202
VT	48	8	45	100	10	40	Sd, C..........†	13,500	12,000	90.8	400
L	66	20	100	125	10	150	G, R...........†	160,300	22,687	14.0	1,550
L	40 / 54	17 / 18	135	100	10	125	Sd, G, R......*	58,335	7,900	13.5	899
L	44	16	40	100	6	40	Sd ....†	12,100	2,227	18.4	3,048
U	52	8½	50	100	15	60	Sd, G.........†	50,575	8,589	17.0	2,095
L	42	12½	40	100	5	75	Sd, G..........†	14,470	1,013	7.0	250
FT	43	8	30	125	5	40	Md, R.........†	1,700	400	24.0	70
								967,177	$114,275	11 8	
UT	54	10	40	120	8	40	C, Md, R......*	35,987	6,864	19.1	1,402
L	52	14½	40	90	8	105	Sd, Md, C, St.*	221,960	21,661	9.7	3,692
FB	54	17⅓	75	90	6	40	BR ....*	7,893	3,900	49 2	83
L	54	13⅝	86	90	6	70	C, Md, Sd, R..*	74,055	4,953	6.7	1,408
M	60	10	..	80	8	65	Sd, C, G, Sh..†	45,171	7 263	16.1	1,667
L	48	15	53	100	8	50	Md, Sd, Si, G.†	48,810	7,423	15.2	475
L	56	19	100	70	13	175	Md, B.........*	72,680	23,546	32.4	4,846
SM	84	11	85	110	5	80	C, Md, Sd.....*	94,820	3,436	3.6	836
SM	108	10	140	125	9	200	C. Mk, Sd.....*	135,775	8,146	6 0	3.880
L	42	16	40	90	10	60	TC ....*	42,100	6,422	15.3	3,504
FB	60	15	75	125	6	70	R, G, C........*	41,420	7,698	18.6	790
FB	60	17	75	106	6	100	R ....†	21,610	8,111	37.5	539
L	54	19	125	90	5	100	Sd, C..........†	97,746	11 301	11.5	500
								940,027	$120,714	12.9	
L	84	19	125	80	11	166	Sd, Md, C, Sp.*	542 027	28,476	5 3	...
RT	72	18	150	90	12	90	Md, Sd, Sp....*	98,122	12,083	12.3	3,415
L	84	23	160	90	12	160	Sd, Md, C, Sp.*	566,631	34.117	6 0	...
L	62	20	100	75	11	36	Md, HP, R....*	81,628	13,098	15.8	1,145
UT	48	8½	..	100	10	25	S ....*	3,180	1,251	39 3	21
PF	46	8½	50	125	3	40	Sd, Md, Sp...*	27 004	3,355	12 4	...
PF	40	9	25	100	3	35	Sd, Md, Sp...*	23,546	3,022	12.8	...
								1,342,138	$ 95,402	7.1	
V	58	8½	50	90	8	59	Si ....*	34,160	5,309	15.5	1,387
L	42	15⅓	40	90	10	60	G ....*	43,433	10,383	24.0	1,894
RT	84	12	80	90	10	75	Sd, G, C.......*	57,186	6,483	11.2	1,702
								134,779	$ 22,175	16.5	
L	60	..	80	100	5	200	Md, Cs.........*	68,950	5,093	7 4	787
L	54	..	60	100	6	90	Md, Cs, R.....*	42,375	5,502	13.0	1,015
L	48	17	55	90	9	120	Sd, G, Md, R.*	91,763	13,913	15 2	2.053
RWT	..	..	150	120	14	250	G, Sd, B......*	109,579	22,102	20 2	2,911
RWT	..	..	120	120	12	250	G, Sd, B......*	122 967	20,736	16.7	2,374
								435,634	$ 67,336	15.5	...
ML	96 / 54	14 / 18	60	70	11	100	†	11,866	$ 16,033	135.0	1,549
LV	80 / 54	6 / 18	70	110	9	100	Md, LR.......†	84,850	28,822	33.9	886
LV	36	7	75	100	9	67	†	115,614	26,152	22.6	1,287
								212,330	$ 71,007	27.4	...
								4,032,085	490,909	12.2	...

1. BUCKET TYPE. BD—Bottom Dump; C—Clamshell; CB—Chain Buckets; D—Dipper; G—Grapple; Gb—Grab; OP—Orange Peel; SB—Sliding Bottom; SD—Scoop Dipper; TD—Teeth Dipper.
2. BOILER TYPE. I—Internal; FB—Fire Box; FbT—Firebox Tubular; FT—Fire Tubular; L—Locomotive; M—Marine; ML—Marine Leg; PF—Plain Flue; RT—Return Tubular; RWT—Roberts W. T.; SM—

OPERATING COSTS OF

Capacity of buckets	Time in commission	Working period for figures given	Actual working time; hours during working period [1]	Quantity handled	Average depth of gravel	Labor and material	Electric power	Water
Cu. ft.			Hr.	Cu. yd.	Ft.	Ct.	Ct.	Ct.
3	....	1 yr.	2,809	173,655	27.0	2.77	0.90	0.14
3	5 yr. 9 mo.	1 yr.	7,216	458,882	26.9	2.03	0.69	...
3.5	7 yr.	1 yr.	....	395,316	35.0	2.83	1.53	0.228
3.5	6 yr. 6 mo.	1 yr.	7,344	461,882	35.0	2.85	1.48	0.195
4	9 yr.	1 yr.	7,057	484,387	20.6	1.83	0.89	0.31
5	6 yr.	1 yr.	....	481,184	25.0	3.28	1.46	0.39
5	2 yr. 5 mo.	1 yr.	....	635,146	27.0	3.14	1.45	...
5	2 yr.	1 yr.	....	582,891	30.0	3.28	2.02	0.32
5	5 yr. 6 mo.	1 yr.	7,344	615,009	25.0	3.06	1.42	0.29
5	4 yr. 6 mo.	1 yr.	....	812,355	36.0	2.30[2]	1.08	...
5	3 yr. 5 mo.	1 yr.	6,798	1,148,480	25.5	0.88	0.52	0.05
5	2 yr. 5 mo.	1 yr.	6,790	1,148,802	29.9	0.82	0.49	0.03
5	4 yr. 7 mo.	1 yr.	6,644	599,614	38.5	1.77	0.92	0.25
7	9 mo. 10 days	1 yr.	5,088	838,885	35.0	1.19	0.69	...
7	1 yr.	1 yr.	6,313	1,114,605	27.6	1.21	0.62	0.03
7	3 yr. 9 mo.	1 yr.	6,390	1,033,694	26.5	1.08	0.64	0.14
7	2 yr. 9 mo.	1 yr.	6,917	1,017,167	28.1	1.10	0.65	0.15
7	3 yr.	1 yr.	6,352	935,322	33.4	1.26	0.85	0.06
7	3 yr.	1 yr.	6,700	1,194,146	27.5	1.05	0.58	...
7.5	2 yr. 11 mo.	2 yr. 11 mo.	13,464	3,458,229	27.9	0.27	0.41	...
7.5	9 mo. 6 days	9 mo. 6 days	5,582	944,879	28.9	0.95	0.58	...
7.5	2 yr. 6 mo.	1 yr.	6,402	1,369,844	70.2	0.99	0.77	...
7.5	2 yr. 6 mo.	1 yr.	6,900	1,281,351	67.8	1.09	0.98	...
8	6 mo.	6 mo.	3,162	583,927	42.5	1.69	0.59	...
8	4 mo. 8 days	4 mo. 8 days	2,369	626,624	24.0	*	*	*
9	5 mo.	5 mo.	....	580,310	51.0	*	*	*
13.5	8 mo.	8 mo.	4,478	1,803,201	19.0	1.02	0.47	...

[1] Total possible time in year's work, 8,784 hours.
[2] Including general expense, management, etc.
[3] Heavy repair-cost due to new tumbler, conveyor-belt, repairs to digging-ladder, screens, etc.
[4] Replacing tumbler-shafts, conveyor-belt, and new screen included in repairs.

Scotch Marine; T—Tubular; U—Upright Tubular; V—Vertical; VT—Vertical Tube.

3. CHARACTER OF DREDGED MATERIAL. B—Boulders; BR—Blasted Rock; C—Clay; Cs—Cinders; G—Gravel; HP—Hard Pan; L—Leaves; LG—Loose Gravel; LR—Ledge Rock; Md—Mud; Mk—Muck; Ml—Marl; R—Rock; Sd—Sand; Sh—Shale; Si—Silt; SM—Soft Mud; Sp—Stumps; St—Stone; TC—Tenacious Clay.

CALIFORNIA GOLD DREDGES.

Repairs	General	Taxes and insurance	Total expense	Remarks
Ct.	Ct.	Ct.	Ct.	
4.15	0.78	0.49	9.23	Difficult digging.[7]
3.28	0.63	0.37	7.00	Working under favorable conditions.
1.74	1.32	...	7.67	
1.71	1.07	...	7.32	Compact gravel land subject to overflow.
2.58	0.65	0.26	6.52	Remodeled dredge, uneven bed-rock, in places shallow.
2.97	1.52	...	9.55	Difficult ground, in places cemented gravel.
2.40	1.28	0.41	8.70	Difficult ground.
2.59	1.37	1.00	9.60	Difficult digging.
3.06	1.14	...	8.98	Difficult digging.
2.95	...	0.35	6.65	Medium gravel with considerable clay, much brush on top soil.
1.77	0.25	0.35	3.80	Loose gravel, heavy overburden of sandy loam.
1.89	0.25	0.16	3.64	Loose gravel, heavy overburden of sandy loam.
4.033	0.47	0.23	7.67	Difficult digging, working against 24-ft. bank.
1.22	0.26	0.17	3.53	Difficult digging, gravel coarse, partly cemented.[8]
1.81	0.29	0.11	4.07	Compact gravel.
2.69[4]	0.34	0.20	5.09	Compact gravel, heavy digging.
2.19[5]	0.28	0.14	4.51	Compact gravel, heavy digging.
3.06	0.31	0.34	5.88	Compact gravel.
2.78	0.32	0.37	5.10	Compact gravel.
1.50	0.24	0.24	4.42[6]	Medium compact bench gravel.
1.30	0.27	0.39	3.55	Medium compact gravel with heavy overburden.
1.95	0.45	...	4.16	Medium gravel overlain with hydraulic tailings.
2.01	0.45	...	4.53	Medium gravel overlain with hydraulic tailings.
1.14	0.28	0.22	3.92	Light gravel dredge working against 10-ft. bank.
*	*	...	2.47	
*	*	...	4.98	Cemented gravel, difficult digging, 20-ft. bank above water level.
0.60	0.12	0.09	2.30	Fine gravel, easy digging.

[5] New steel spud and screen in repairs.
[6] Depreciation charges included in total expense.
[7] A 7 ft. dredge is now working this ground at a profit.
[8] This dredge successfully replaced an open-connected bucket-dredge which could not handle the ground at a profit.
* Segregated costs not given.

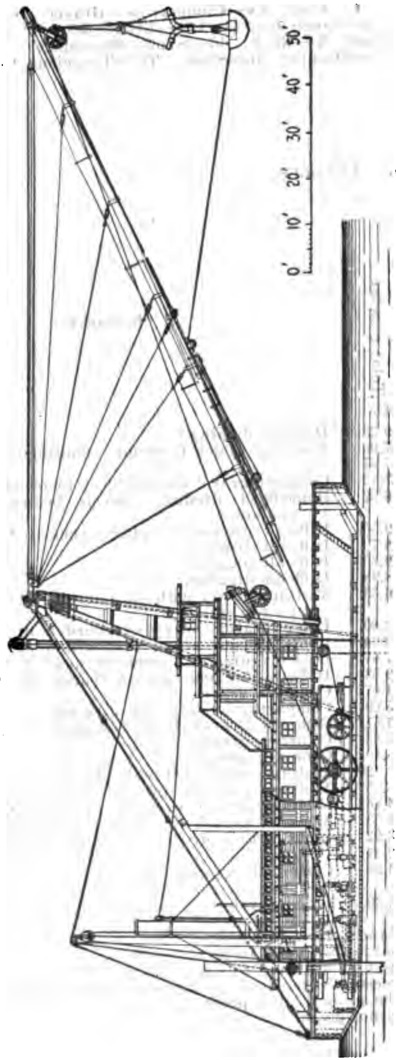


Fig. 138. Clam Shell Dredge "Delta" of California Development Co.

Cost and Repairs of Dredges.

	Year	Dipper dredge Ajax, bought 1877; built 1876. (Oak hull.)	Dipper dredge Vulcan, built 1882–1883. (Oak hull.)	Dipper dredge Phoenix, built 1885. (Oak hull.)	Suction dredge Geyser, built 1893. (Fir hull.)	Suction dredge Hecla, built 1900–1901. (Fir hull.)
Original cost	....	$11,300.00	$19,450.00	$19,525.00	$ 4,704.44	$27,708.66
Repairs to and inc.	1890	....	2,840.82	2,848.27	....	....
Repairs	1891	....	....	199 28	....	....
Repairs	1892	†11,539 60	*1,525.61	797 78	....	....
Repairs	1893	536.03	*3,373.06	766 71	....	....
Repairs	1894	*5,801.75	27.92	391 34	2,032.36	....
Repairs	1895	1,494.86	1,337 78	*1,582.93	1,661.20	....
Repairs	1896	713 00	1,904 42	*3,033 18	639.33	....
Repairs	1897	1,177.85	903 49	806.32	1,299.48	....
Repairs	1898	423.26	*2,256.89	1,166 02	1,462.74	....
Repairs	1899	1,079.07	*3,887.66	1,123.26	1,344.31	....
Repairs	1900	1,029.55	614.45	1,360 17	1,646 45	....
Repairs	1901	490.69	349 59	931 50	1,177.04	....
Repairs	1902	747.92	822.36	889 86	1,266.11	1,081 41
Repairs	1903	1,425.36	1,530.67	306 70	1,905.00	3,405.09
Repairs	1904	449.03	2,223.93	999 13	1,040.71	3,395.78
Repairs	1905	709.33	1,955.35	903.92	2,793.23	3 650 24
Repairs	1906	2,646.86	2,546.13	1,396 33	2,171.35	1,677 00
Repairs	1907	1,709.79	1,745.82	1 818.27	1,960.88	2,681.56
Repairs	1908	1,210.24	2,837.16	‡7,859.91	3,512.48	1,044 20
Repairs	1909	1,829.54	2,986.84	‡11,721.38	2,713.74	2.692.51
Repairs	1910	1,788.47	1,996.41	1,674.71	2,897.12	1,421 59
Totals to date		$48,102.20	$57,116.36	$62,101.97	$36,227.97	$48,758.04

* New hull, etc. † Repairs to Dec. 31, 1892. ‡ Burnt and rebuilt.

tity handled varied with the kind of material from 3 to 8 cu. yd. extremes. On the Sacramento River, under good conditions, 150,000 cu. yd. per month were handled.

Monthly expenses:

Maintenance and operaton	$2,500.00
Interest on investment at 6%	400.00
Taxes and insurance	200.00
Deterioration	700.00
	$3,800.00

The foregoing "monthly expenses" is a minimum; ordinarily, in Mexico, the monthly expense was $5,000. The average cost in Mexico was 4 to 6 cents per cubic yard.

Ladder Dredges. Bucket elevator dredges are known as bucket ladder dredges, chain bucket dredges or endless bucket dredges. They are used principally abroad, and in the United States mainly on canal work. They are very good where the cutting is light and also in finished work, for they leave a smooth bottom.

In Trans. A. S. of M. E., 1886–7, Mr. A. M. Robinson says that 1 hp. on an elevator dredge will excavate 5 to 9 cu. yd whereas in a dipper dredge 1 hp. will excavate about 3¾ cu yd. in 32 ft. of water.

In *Engineering News*, August 4, 1892, a Bucyrus bucket elevator dredge is described. The average daily output was 1,180 yards in 10 hours in soft sponge material. The crew consisted of six men and the cost of excavation per cu. yd. was about 3c.

In a paper read before the Institute of Mining and Metallurgy of Great Britain on April 19, 1906, Mr. E. Seaborn Marks and Mr. Gerald N. Marks gave descriptions of bucket dredges used for dredging gold in Australia. A total of 50,000 to 70,000 sup. ft. of timber are used in building a pontoon which will measure from 70 to 90 ft. or more in length, about 30 ft. in width and 6 ft. 6 in. in depth. These dimensions vary with the weight of machinery and the general arrangement and design of the plant. Australian hard woods are excellent material, on account of their strength and durability, but their weight is an objection should a shallow draft be required. In this case Oregon pine would be preferable for planking, with hard wood framing. If hard wood is not procurable, pitch pine should be used for framing, as Oregon does not hold spikes securely. All pontoons are coated with tar to preserve the timber, after the seams have been calked, and are plated with ⅛-in. steel plate for 6 ft. at either end as a protection from sunken logs. In countries where transportation is difficult and

skilled labor scarce, pontoons are constructed of steel plates and girders. These are built in the works and afterwards taken to pieces and shipped in sections. The cost of building three plants and pontoons is given below, but these prices will necessarily vary with the cost of transporting, labor and such items:

(1) A pontoon of hard wood with an inner skin of Oregon pine cost $5,760. The complete plant cost $32,500. This machine is a screen dredge with a discharge into a sluice run. A similar plant with a tailings elevator (in which case the screen would be lowered to within a few feet of the deck and power thereby saved in pumping up the water for washing purposes) would cost approximately $5,000 more.

(2) The pontoon constructed of Oregon planking spiked to hardwood framing of cheap and effective design cost $4,140. The complete plant cost $27,500. The frame has diagonal struts forward, on the lower one of which the frame is pivoted and can be moved up and down to alter the dredging depth.

(3) A pontoon, built on somewhat different lines with diagonal and cross braces, is constructed of Oregon planking with hard wood frames and is suitable for working light, shallow grounds. The gantry from which the ladder is swung is constructed of steel in the first two pontoons but in this case it is of Oregon pine. This dredge has a combination of sluice box, screen and elevator and can be lengthened so as to do the combined work of a screen and tailings elevator. The cost of the plant complete was $30,000. The buckets in general use were of 4½ cu. ft. capacity of 5-16 to ½ in. steel. They varied, however, from 3 to 12 cu. ft. capacity. The boiler generally used is of the return tube marine type with internal flue working up to 120 lb. per sq. in. It is usually 6 ft. 6 in. in diameter and 8 ft. long (12 ft. over all with combustion chamber and smoke box), fitted with 48 tubes and will give 75 I. H. P. The engine is from 16 to 25 hp., making 125 revolutions per minute. The 16 hp. one has compound cylinders 8 x 14½ and 14 x 14½ in. A belt from the fly wheel connects with the first motion shaft, and the pulley works a 12-in. centrifugal pump.

The following table is the result of two dredges used in dredging gold.

	No. 1 Dredge	No. 2 Dredge
Full working time for a year	52 wk. or 7,488 hr. in each case	
Actual time worked	6,161 hr.	5,572 hr.
Percentage of lost time	17.70%	25.6%
Gross capacity of dredge	130 cu. yd. per hr.	112.5 cu. yd. per hr.
Material actually treated	325,896.3 cu. yd.	303,360 cu. yd.

*Percentage of material treated relatively to gross capacity for time worked	40.6%	48%
Gold recovered	1,198 oz. 12 dwt.	1,393 oz. 17 dwt. 22 gr.
Net value	£4,815 19s 2d	£5,103 18s 1d
Total working expense	£3,321 18s 8d	£4,119 16s 7d
Net profit	£1,494 0s 6d	£1,954 1s 6d
Value per cu. yd. of material treated	1.76 gr. or 3.5 d	2.2 gr. or 4d
Cost of treatment per cu. yd.	2.4d	2.4d

* Calculated in each case with 4½ cu. ft. buckets, but in the first 13 buckets and in the second 11.25 buckets per minute were delivered.

The following table gives the expenditures during the week ending Aug. 17, 1905:

	No. 1 Dredge			No. 2 Dredge		
	£	s	d	£	s	d
Wages	30	17	1.2	30	15	11.2
Repairs and renewals	10	15	4.4	6	10	1.7
Fuel	8	17	7.4	5	15	11.9
General expenses	0	15	2.5	1	5	10.5
Traveling expenses	0	3	3.8	0	2	3.5
Rent on leases	0	10	8.9	3	19	9.7
Freight and cartage	1	0	7.2	1	1	2.0
Insurance	0	11	7.5	0	15	2.3
Dredge supplies	0	16	1.8	0	14	4 2
Office and management	9	9	10.5	9	10	8.7
	63	17	7.2	60	11	5.7

A bucket ladder dredge and special conveyor were built at Adams Basin on the New York Barge Canal during the summer of 1909.

The dredge itself is floated on two steel pontoons which are parallel to each other and are braced together by a rigid framework. A gantry projects in front of and between the pontoons and supports the ladder, which extends to the bottom of the canal. The buckets each have a capacity of 5 cu. ft. From a hopper at the top of the ladder the material is discharged upon a belt which in turn discharges into a second hopper and a second belt at the rear of the dredge. A third belt is carried on a separate pontoon, along a steel cantilever frame which carries the belt 40 or 50 ft. to the bank. Each belt is operated by a separate motor receiving power from the dredge. The plant cost $70,000.

The cost of the work for the first three months was as follows:

August, 1909; 18,638 cu. yd. excavated:

Coal and oil	$1,984.50
Fifteen tons coal for hoisting engine, at $2.85	42.75
Miscellaneous supplies for hoisting engine	5.25
Miscellaneous supplies for hoisting engine and derrick	6.48
Hauling supplies	54 00
Crew of dredge	2,296.68
Total cost	$4,389.66

Cost per cu. yd., 23.6 cents.

Interest and depreciation, etc., were not to be included, on account of commencing work in this month.

Drains and scrapers supplemented the dredge, moving 6,244 yd. for a total of $1,280.50, or 20.5 ct. per cu yd. The cost of wooden forms and of spreading and compacting amounted to $1,193.25 for 10,015 cu. yd. of embankment, or 11.9 ct. per cu. yd.

September, 1909; 32,000 cu. yd. excavated:

Interest, depreciation and repairs	$2,205.00
180 tons coal, at (2 tons per shift)	513.00
150 gal. gasoline at 12 ct.	18.00
Oil (80 gal. at 19 ct.; 60 gal. at 35 ct.)	36.20
1,200 lb. grease at 8 ct.	96.00
200 lb. waste at 8 ct.	16.00
Teams	245.00
Labor	2,827.00
Total cost	$5,956.20

Cost per cubic yard, 18.6 cents.

A total of 90 eight-hour shifts were worked The cost of the embankment was as follows:

Labor, spreading and compacting	$3,151.50
Hauling form lumber	177.16
Cost form lumber	1,125.00
General	290.00
Labor on forms	828.32
Hauling supplies	55.00
Total	$5,626.98

Only 11,000 cu. yd. were allowed for the above work on embankment, as the forms gave way and the soft material had to be scraped back. This brought the cost of embankment for the month up to 51.1 ct. per yd.

October, 1909; 25,500 cu. yd. excavated:

Interest and depreciation	$2,351.66
186 tons coal at $2.85	530 10
Labor	3,145.58
Teams	5.00
Oil, grease and waste	153.09
Gasoline	18.60
Repairs	18.90
Total cost	$6,222.93

Cost per cubic yard, 24.4 cents.

A total of 93 eight-hour shifts were worked. The cost of embankment was as follows:

Labor, spreading and compacting	$2,898.25
Forms	567.50
Erection	108.50
Hauling	95.00
Total	$3,669.25

This gives for 21,800 cu. yd. of embankment a cost of 16.9 ct. per cu. yd.

Recent Examples of California Gold Dredges with Costs of Dredging. A concise statement of practice in California in dredge construction for reclaiming gold from underwater gravels is taken from an elaborate paper by Mr. Charles Janin in the bulletin for March, 1912, of the American Institute of Mining Engineers. The paper also gives a table of costs which are of general interest in view of the increasing favor with which elevator dredges are being considered in America.

The modern California type dredge, with close-connected buckets, spuds and belt conveyor for stacking tailings, was a gradual development through years of experimenting. This dredge embodies the ideas of successful operators, and it is generally conceded that dredge construction and operating methods in California are far ahead of those in any other country in the world. The dredges built in California cost from $25,000 to $265,000 each; a standard 8.5 cu. ft. boat costing from $150,000 to $175,000, according to conditions to be met in operation. With the great improvements made in dredge construction, and corresponding reduction in operating costs, areas that were at first considered too low grade to be equipped with a dredge are being profitably worked.

California dredges vary in size from 3.5 to 15 cu. ft. buckets. In Alaska some dredges are equipped with buckets as small as 1.25 cu. ft. to dig shallow ground, and are reported to be working profitably. While electricity is the ideal power for operating dredges, steam has been successfully used on a number of installations, and experience has proved the merits of the gasoline distillate engine for this work. There seems little doubt that the successful development of the gas producer for the generating of electric power will prove an important factor in considering future dredging of gravel areas in districts where electric power or water power for the installation of hydro-electric plants is not at present available.

One of the largest gold dredges operating in California was put in commission at Hammonton, in Yuba River basin, August 10, 1911. This dredge was built by the Yuba Construction Co. and is one of five practically similar dredges built by the same company this year. It required 820,000 ft. of lumber for the hull and housing the hull; its dimensions are 150 x 58.5 x 12.5 ft., with an overhang of 5 ft. on each side, making 68.5 ft. total width of housing. The digging ladder is of plate girder construction and designed to dig 65 ft. below water level, and is equipped with ninety 15 cu. ft. buckets arranged in a close

connected line. The entire weight of the digging ladder and bucket line is approximately 700,000 lb. The washing screen is of the revolving type, roller driven, and is 9 ft. in diameter by 50.5 ft. long and weighs 111,721 lb. Two steel spuds are used, each weighing over 44 tons. The ladder hoist winch has a double drum and weighs 67,016 lb. The swinging winch consists of eight drums and weighs 34,193 lb. The stacker hoist winch weighs 3,722 lb. The gold saving tables are of the double bank type and have an approximate riffle area of 8,000 sq. ft. The tailings sluices at the stern can be arranged to discharge the sand from the tables either close to the dredge or at some distance behind. The conveyor stacker belt is 42 in. wide and 275 ft. long, on a stacker ladder of the lattice girder type, 142 ft. long. Nine motors are in use on the dredge with a total rated capacity of 1,072 hp. The total weight of hull and equipment is 4,640,862 lb.

Natoma No. 10 dredge, now under construction, is equipped with 15 cu. ft. buckets, and will have a steel hull, being the first dredge operating on a steel hull in California. The hull will be 150 x 56 x 10.5 ft. and will have a total weight of 920,000 lb. This will be about one-half the weight of a wooden hull to carry the same machinery, and the draft of the boat will be considerably lighter. This boat will be in operation in April, 1912.

The machinery of some California dredges has been dismantled and moved to other fields and installed on new dredges. The estimated cost of dismantling the Scott River dredge, which was equipped with 7.5 cu. ft. buckets, building a new hull, installing machinery, including a 28-mile haul, with a freight cost of over 1 cent per pound and building a 5-mile transmission line, was $80,000. The Butte dredge was put in operation in November, 1902, and dismantled in July, 1910. It was equipped with 3.5 cu. ft. buckets. The machinery is being placed on a new hull and includes a new bucket line of 4 cu. ft. buckets. The cost of the installation has been estimated at $30,000.

The dipper dredge has been successfully operated on small areas at Oroville and elsewhere, but does not meet with approval among dredge operators in general, who contend that the efficiency of these boats, both as to yardage and gold saving capacity, is not up to that of the standard type. These boats have a low first cost (about $25,000, f. o. b. factory) and are built with buckets of from 1.25 to 2.5 cu. yd. capacity. It is claimed by the dealers and some operators that under the following conditions there is a field for this type of dredge: (1) Where the ground is somewhat shallow; (2) where the extent of the ground

is not sufficient to warrant the installation of a costly dredge; (3) where the material is of a rough character, boulders and stumps; (4) where the ground is mixed with more or less clay, as the dipper will relieve itself notwithstanding the adhesiveness of the material.

What seems to be a record in dredge construction is the building of the dredge for the Julian Gold Mining & Dredging Co. on Osbourn creek, near Nome, Alaska. This dredge was constructed by the Union Construction Co. of San Francisco. The dredge was shipped from San Francisco on June 1, arriving at Nome June 13. On June 17 the company commenced hauling material, and on July 22 the dredge was completed and operations started. The dredge hull is 30 x 60 x 6.5 ft. It is equipped with 34 open connected 2.75 cu. ft. buckets, and is designed to dig 14 ft. below water level. Power is furnished by gasoline engines as follows: One 50 hp. for digging ladder, winches and screen; one 30 hp. for pump; one 7 hp. for lighting apparatus; a total of 87 hp. Distillate costs at Nome 21 cents per gallon. Operating expenses at present range from $110 to $125 per day, and the capacity of the dredge is from 1,000 to 1,300 cu. yd. per day, indicating an operating cost of from 10 to 11 cents per cubic yard, exclusive of repairs. The cost of the dredge complete and in operation was $45,000.

The operating cost of dredging is always a matter of interest, but working costs cannot be fairly used in comparison unless uniform methods of determining them are employed, and also unless operating conditions are somewhat similar. As in other branches of the mining industry, it may also be said that the apparent operating cost is in a great measure a matter of bookkeeping. It is interesting to note the following average operating cost per cubic yard of the large companies working in California during 1910. The Yuba Construction Co., for the year ended February 28, 1911, handled 13,970,728 cu. yd. at a total cost of 5.67 cents per cubic yard. The Natomas Consolidated handled, for the year ended December 31, 1910, a total of 15,989,525 cu. yd. at a total cost of 4.52 cents per cubic yard, and during the six months ended June 30, 1911, a total of 10,-793,891 cu. yd. at a total operating cost of 3.78 cents per cubic yard. This company has put in commission during 1912 three dredges with buckets having a capacity of 15 cu. ft. These two boats are now satisfactorily handling ground that for a long time was considered too difficult for economical dredging. The gravel is deeper and more compact than any other in the district, and dredge No. 8 is handling ground containing much stiff clay. The Oroville Dredging, Ltd., for the year ended July

31, 1910, handled 5,661,612 cu. yd. at a total cost of 5.05 cents per cubic yard.

Hydraulic Dredges. The ordinary hydraulic dredge has a centrifugal pump to raise the earth and water, and a rotary cutter or a water jet to loosen the material. The discharge is carried through pipes supported on scows. Tough clay with very large boulders cannot be handled, and while sharp sand is excavated readily it cuts the pump and discharge pipe badly; but for soft material the hydraulic dredge is very satisfactory.

In the Transactions of A. S. C. E., 1884, Mr. L. J. Le Conte gives the cost of dredging in Oakland Harbor, Cal. The average output was 30,000 cubic yards per month for eight months. The best output was 60,000 cubic yards in 23 days of 10 hours each, with delivery pipe 1,100 ft. long. An output of 45,000 cubic yards in 19 days of 10 hours each was accomplished when the lift was 20 ft. above the water, with a pipe 1,600 to 2,000 ft. long. The dredge was equipped with a 6 ft. centrifugal pump, two 16 x 20 in. engines for the pump, two 12 x 12 in. engines for operating the cutter, etc., and two 100 hp. boilers. On an average, 15% of the material pumped was solid, but up to 40% all solids could be carried. The daily cost was as follows:

Coal, oil and waste	$ 35.75
Crew of 9 men	25.00
Cook and board	7.00
Interest, depreciation and insurance	25.55
Repairs	10.00
Total	$103.30
10 men on pipe line	20.00
1,200 cu. yd. at 10 ct.	$123.30

Mr. J. A. Ockerson, in the Transactions of A. S. C. E., 1898, gives the following cost of operating three dredges:

Name of dredge	Alpha	Beta	Gamma
Cost	$87,000	$217,000	$86,000
Capacity, sand per hr.	600 cu. yd.	2,000 cu. yd.	800 cu. yd.
Draft	4 ft. 10 in.	6 ft. 10 in.	4 ft. 3 in.
Main engines	300 hp.	2,000 hp.	500 hp.
No. centrifugal pumps	1	2	1
Diameter centrifugal pumps runner	6 ft.	7 ft	5 ft. 9 in.
Diameter discharge pipe	30 in.	33 in.	34 in.
Delivery head	20 ft.	29 ft.	37 ft.
Velocity of discharge, per second	10 ft.	14 ft.	10 ft.
Agitators or cutters	6—2½-in. jets	6 cutters	9—2½-in. jets
Coal used, 24 hours	500 bu.	2,088 bu.	400 bu.
Cost of running per day	$97.00	$221.63.	$100.51

* Add $37 for steam tender and $12 for pile sinker per 12 hour.

Mr. Emile Low describes a small dredge used by the United States Government at Warroad River, Minn. The dredge is

of the "seagoing hopper type" with stern wheel, but is also adapted and equipped for use with a supported discharge pipe for river channel and river harbor dredging. The dimensions are: Length of hull, 100 ft.; width midship at main deck, 27 ft.; depth of hull midship, 8 ft. 6 in.; length over all, including stern wheel and revolving cutter on the bow, 158 ft.; height of hull and superstructure, 25 ft. 4 in.; draft light, 4 ft. 2 in.; draft loaded, 6 ft. 4 in. The machinery consists of the following:

Two 12 in. centrifugal pumps.

One 16 hp. vertical engine operating the revolving cutter.

One 20 hp. horizontal engine operating the cutter hoist, chain drums and rope spools.

Two 10 x 60 in. stern wheel engines.

One 6 x 10 in. duplex force pump.

Four hand power worm gears for manipulating the sand pit shutters.

Two 75 hp. Scotch marine boilers.

The pumps are arranged to take material through trailing suction ends from both sides of the dredge and one pump is also connected with the suction end of the cutter for dredging in clay and other hard material. The dredge, complete with wood barge, pipe floats and small boats, cost $29,130. It commenced operation on May 7, 1904, and between that day and June 30 accomplished the excavation of 1,380 lin. ft. of channel with an average width of 100 ft. and a mean depth of 8 ft. The total excavation was 8,625 cu. yd. at an average cost of 21⅔ cents per cu. yd. for all expenses, including labor, fuel, supplies, subsistence, etc. The cost of subsistence per ration was 44 cents. The material dredged was equal quantities of hardpan and mud, the latter full of tough, fibrous roots. Stormy weather delayed the work 5½ days. The total excavation for the fiscal year July 1, 1904, to June 30, 1905, was 55,205 cu. yd. The average cost of excavation, including charges on account of the plant used, was 13.03 cents per cu. yd., and the cost of subsistence per ration 39 cents.

The following tables give some data concerning the best six hydraulic dredges in use on the Mississippi River.

ORIGINAL COST OF PLANT

Name	Dredge	Tender	Pile sinker	Total
Delta	$124,940	$47,862	$2,884	$175,686
Epsilon	102,000	47,862	2,884	152,746
Zeta	109,000	47,862	2,884	159,746
*Iota	100,480	.....	....	100,480
*Kappa	134,600	.....	....	134,600
*Flad	134,600	.....	....	134,600

* Self-propelling. Average cost for non-propelling, $162,726; average cost for self-propelling, $123,227; average cost of one plant, $142,976 +.

Repairs, Renewals, Alterations and Betterments to Plant

Name	Date of delivery	Repairs and renewals	Alterations and betterments	Totals
Delta,	Aug., 1897	$28,761.58	$20,634.20	$49,395.78
Epsilon,	March, 1898	21,381.17	1,094.35	22,475.52
Zeta,	March, 1898	20,318.06	1,128.17	21,446.23
Iota,	Aug., 1900	13,155.28	8,174.19	21,329.47
Kappa,	July, 1901	7,533.16	4,664.95	12,198.11
Flad,	July, 1901	6,605.63	4,737.61	11,343.24
Tenders,	Oct., 1899	....	....	*10,718.93
Pile sinkers,	Dec., 1898	....	....	*883.15

* Average of 4. Repairs and renewals, average of 6, $16,292.48; repairs and renewals (omit Delta), average of 5, $13,798.66; alterations and betterments, average of 6, $6,738.91; alterations and betterments (omit Delta), average of 5, $3,959.85.

The dredges Delta, Epsilon and Zeta are non-propelling, requiring the service of a tender and pile sinker, and Iota, Kappa and Flad are self-propelling.

The average repairs, etc., per dredge for the last 3 years were $1,868.61.

Cost of Field Operations

Name	Number of seasons operated	Total cost field operations	Total hours in commission	Total working hours
Delta	7	$135,651.40	16,648	7,605
Epsilon	7	120,444.42	14,891	5,159
Zeta	7	100,114.57	13,243	4,037
Iota	5	80,942.51	12,137	3,127
Kappa	4	58,780.57	9,411	2,882
Flad	4	62,218.32	9,561	3,200

Name	Average cost per month in commission	Cost of material used in field repairs	Average cost per month excluding field repairs
Delta	$5,866.71	$4,595.91	$5,667.95
Epsilon	5,823.65	4,310.65	5,615.23
Zeta	5,443.06	3,872.81	5,232.51
Iota	4,801.73	3,290.19	4,606.55
Kappa	4,497.08	1,881.42	4,353.14
Flad	4,685.41	997.79	4,610.27

Including field repairs, average monthly cost for operating a non-propelling dredge with tender and pile sinker, $5,711.14; same for a self-propelling dredge, $4,661.41; excluding cost of material for field repairs, the monthly cost of operating a non-propelling plant, $5,505.23; same for a self-propelling plant, $4,523.32.

The rated capacity of these dredges, based on an assumed velocity of 13 ft. per second in the discharge pipe and a carrying capacity of 10 per cent. of sand, is 1,200 cubic yards per hour for the Delta and 1,000 cubic yards for each of the other dredges delivering through 1,000 ft. of pipe. In tests made in 1907, the following results were obtained:

CAPACITY TEST OF THREE DREDGES

Name	Aver. velocity per second	Per cent. of sand	Average sand per hour
Delta	15.10 ft.	14.69	1,850 cu. yd.
Epsilon	16.78 ft.	20.68	2,553 cu. yd.
Zeta	16.48 ft.	11.14	1,364 cu. yd.

Field tests under actual conditions were made in 1898.

Dredge	Duration of test, hours	Average cu. yd. per hour	Remarks
Delta	27.38	1,295	Sand, max. rate 2,550 cu. yd. p. hr.
Epsilon	24.93	1,305	Sand.
Zeta	62.92	652	Blue clay and sand.

Tests made with only water pumped in 1902 would give the deductions:

CAPACITY TESTS

Dredge	Average velocity	Cu. yd. per hour 15% sand	Cu. yd. per hour 10% sand	Length of pipe
Delta	16.65	2,160	1,440	500 ft.
Epsilon	21.20	2,404	1,600	500 ft.
Iota	18.36	2,114	1,400	500 ft.
Kappa	21.35	2,342	1,560	240 ft.
Flad	16.75	1,944	1,296	480 ft.
* Iota	21.30	2,342	1,560	500 ft.

* With shrouded runner.

The actual averages of all the dredges in all materials from clay to sand were: 1901, 567.0 yards; 1902, 481.6 yards; 1903, 422.9 yards; 1904, 537.1 yards; average, 500.0 yards. This average of 500 yards per hour can be depended on, under normal conditions, for 20 hours per day and 25 days per month. Allowing 10% for idle time, this gives 252,000 yards per month, The season of 1904 lasted four months, on which basis 908,000 cubic yards per season could be accomplished.

The contract price of the Harrod, under construction in 1907, complete with pipe line and all auxiliaries, was $238,998.17. Its rated capacity based on an estimated velocity of 22 ft. per second in the discharge pipe and a carrying capacity of 10% of sand is 2,100 cubic yards per hour. The cost of operating the Harrod is assumed to be $5,500 per month while in commission.

The following notes on the hydraulic suction dredge are from U. S. Dept. of Agr., Bul. 230:

For the construction of the larger levees the use of the hydraulic suction dredge is entirely feasible in connection with the use of other excavating machines. By the construction of the muck ditch a retaining bank will be built to as great height

as the earth can be made to stand. A similar retaining bank will be constructed at the other toe of the levee by depositing earth excavated from the nearest margin of the ditch. The space between the two retaining walls can then be filled by a hydraulic suction dredge, the discharge pipe being supported by a cantilever. This machine (Fig. 139), in its present state of development probably represents the most economical method now in use for excavating very large channels, unless the ladder dredge be excepted.

The following table indicates the cost of operating a hydraulic suction dredge on the New York Barge Canal in 1908. The

Fig. 139. Hydraulic Suction Dredge, Showing Discharge Pipe Supported by Cantilever.

dredge in question is of modern construction, has a 20-inch discharge pipe, and cost $115,000. A large part of the excavation was in stiff clay, though a part was in sand. The clay was of such firm texture that after remaining on the ground over winter the pieces had the same shape as when they were discharged from the end of the pipe line, still showing the marks of the cutter. While removing the old rock wall of the canal, the dredge was stopped sometimes twenty times a day, it is said, for removing boulders from the pump. Once during the season the dredge was sunk to the bottom of the canal. Otherwise the work was favorable, and the excavation made was representative of the capacity of the machine in ordinary clay soil. The charge against plant is intended to cover interest

and depreciation at 15% per annum. Under "Material" are included coal waste, tug hire, and similar items.

Cost of Operation of Hydraulic Suction Dredge on the New York Barge Canal for the Season of 1908

Item.	April.	May.	June.	July.
Labor	$3,670.95	$5,169.29	$5,615.75	$ 5,835.14
Plant	408.30	1,367.60	1,677.85	1,735.50
Material	1,900.62	2,558.88	2,263.16	2,446.45
Total for month	$5,979.87	$9,095.77	$9,556.76	$10,017.09
Yards excavated	120,673	204,838	203,474	207,520

Item.	Aug.	Sept.	Oct.
Labor	$5,985.87	$4,993.11	$4,834.14
Plant	1,631.85	1,692.85	1,791.15
Material	2,320.92	2,430.05	2,573.50
Total for month	$9,937.94	$9,116.01	$9,198.79
Yards excavated	174,395	231,473	214,438

Unit cost for the season, 4.63 cents per yard.

An examination was made of several suction dredges on the New York Barge Canal and of the material excavated by them. In only one instance was the material at all comparable with that to be excavated in building the floodway levees, and in that instance the material was being removed at a cost of about 2½ or 3 cents per cubic yard, including all cost of maintenance, depreciation, repair and interest. The work planned for this type of machine on the St. Francis project is the excavation of large ditches outside the floodways, using the earth for constructing levees, and in dredging the channels of Tyronza and Little rivers. In the former case the work is estimated at 10 cents per cubic yard plus the cost of clearing and grubbing the ditch section at $150 per acre. In the second instance the work is estimated at 9 cents per yard, including the cost of clearing banks to enable the material to be deposited. This dredge can be used to advantage also for constructing two or three of the largest lateral ditches, which empty into ditches along the floodway.

In *Engineering-Contracting*, Vol. XXXV, No. 8, the following description is given of a hydraulic dredge, its tenders and capacities, etc.:

This dredge was used to fill in part of the Lincoln Park extension, Chicago, and was purchased in 1907. It is of the open end type, with a steel hull 148 ft. long by 38 feet wide and 10½ ft. deep. The main pump has 30 in. suction and discharge, and the main engines are of the triple expansion marine type of 1,200 i. h. p. The two double-ended marine boilers,

10 ft. 6 in. by 18 ft. long, with eight corrugated furnaces, were fitted at the beginning of last season with underfeed stokers. The installation of engine room auxiliaries includes condenser, independent air pump, independent circulating pump, fire and bilge pumps and an electric light outfit. The rotary cutter is adapted to hard clay material and its edges are of hard steel and are movable. Two seasons' work have worn the cutting edges badly and manganese steel will probably be substituted.

Fig. 140. View of Pontoon Discharge Pipe Used in Connection with the 30-in. Hydraulic Dredge.

The dredge is anchored by heavy spuds operated by power. It can make a radial cut of 175 ft. wide with a maximum depth of 35 ft. The dredge is provided with a complete repair shop and living quarters for the crew.

The pipe line adopted has a central conduit 30 in. in diameter carried by two cylindrical air chambers 33 in. in diameter. The sections are 95 ft. long and are joined with the usual rubber sleeve. The material excavated was very stiff gumbo.

I. TIME REPORT OF DREDGE "FRANCIS T. SIMMONS" FOR 1910

1910.	Available Working Time. Hrs.	Pumping Time. Pct.	Weather. Pct.	Misc. Pct.	Total. Pct.
April	624	47.0	36.5	16.5	53.0
May	600	57.7	19.0	23.3	42.3
June	624	80.0	1.0	19.0	20.0
July	600	68.4	14.0	17.6	31.6
August	648	52.0	29.0	19.0	48.0
September	600	63.5	9.5	27.0	36.5
October	624	54.0	18.0	28.0	46.0
	4,320	60.2	18.2	21.6	39.8

II. Analysis of Working Time

September, 1910.	Hrs.	Mins.	Pct.
Total available time	600	..	....
Dredge worked	381	20	63 ½
Delays	218	40	36 ½

Causes of Delays:	Hrs.	Mins.	Pct.
Weather	57	5	9.5
Short pipe	31	40	5.28
Suction pipe, pumping and plug	11	20	1 89
Pontoon line	31	55	5.32
Swinging cables	15	10	2 52
Main engine	24	..	4.0
Spud engine	..	25	0.08
Cutter engine	..	..	....
Cutter shaft	..	..	....
Moving dredge to new cut	5	5	0.82
Towing and preparation	34	5	5.68
Miscellaneous	1	10	0.19
Stones	6	45	1.12
	218	40	36.40

III. Cost of Operation and Repairs of Dredge, 1910; Total Time in Commission, 4,320 Hours

Operation.	Totals.	Per. hr.	Per cu. yd.
Labor	$13,855.45	$ 3 2073	$0.0243
Fuel	17,000.35	3.9353	.0300
Supplies, tools, sleeves, oil, etc.	4,323.52	1.0008	.0076
Commissary labor and supplies	6,010.90	1.3914	.0104
Field repairs, labor and material	6,040.82	1.3983	.0106
Tug service	13,587.83	3.1453	.0238
Derrick service	327 20	.0757	.0005
Motor boat	584.00	.1352	.0010
Insurance	3,500.00	.8102	.0060
Winter repairs and fitting up:			
Labor	5,267.68	1.2194	.0093
Material	2,164.25	.501	.0037
Fuel commissary and tools	1,025 41	.2374	.0018
Tug service	753.08	.1743	.0013
Totals:			
Operation	65,230.07	15.0996	.1142
Repairs	9,210.42	2.1320	.0161
Operation and repairs	$74,440 49	$17.2316	$0.1303

IV. Four Years' Operation of Dredge

Cubic yards	457,242*	672,815*	518,920*	570,243†
Cost	$54,241.19*	$88,459.17*	$69,202.32*	$74,440.49†
Cost per cubic yard	$0.118	$0.131	$0.133	$0.130
Hours in commission	2,940	27.6	3,291	4,320
Hours pumping	1,088=37 %	4,500=60.6%	2,117=64.3%	2,599
Hours delayed account weather	683=23.2%	636=14.4%	294= 9.0%	788=18 %
Hours delayed, miscellaneous	1,169=39.8%	1,100=25 %	880=26.7%	933=21.6%
Hours delayed, total	1,852=63 %	1,736=39.4%	1,174=35.7%	1,720=39.8%

Output per pumping hour, cubic yards	426	245.8	245	220
Cost of coal	$10,131.04	$16,050.68	$11,584.37	$17,000.35
Cost of coal per cu. yd.	$0.022	$0.024	$0.022	$0.03

* Based on calculation of cut measurement.
† Based on calculation of place measurement.

The operating crew of the dredge is as follows:

	Per mo.
1 Chief operator	$150.00
1 Assistant operator	125.00
1 Chief engineer	150.00
1 Assistant chief engineer	110.00
4 Oilers	66.00
4 Firemen	66.00
4 Coal passers	55.00
2 Spudmen	66.00
1 Janitor	55.00
8 Deckhands	55.00
Commissary:	
1 Steward	86.00
1 Second cook	40.00
1 Porter	40.00

The following data are for the year 1911:

V. Time Report of Dredge, 1911

Available working time, hours	4,620
Pumping time, hours	3,288½
Pumping time, percentage of total time	71.2
Delays:	Hours.
Weather, 6.2%, or	288
Miscellaneous, 22.6%, or	1,043½
Total delays, 28.8%, or	1,331½

The best month's work was in November, when the working time efficiency was 79.5%. The dredge was started for the year on April 15, during which month the working time was 65% of the total. The dredge went out of commission November 30. The working season, then, was 7½ months, or 62.5% of the year. In calculating interest charges on this equipment, the monthly interest must be taken at $1/12 \times \frac{100}{62.5} \times$ annual interest.

VI. Cost of Dredge Operation and Repairs

Total yardage 735,425

Operation.

	Sub-totals.	Cost per cu. yd.
Labor	$18,573.85	
Administration	1,112.56	
Watching	178.66	
Total	$19,865.07	$0.027

Fuel	$17,726.58	0.024
Supplies, tools, sleeves, oil, etc	6,786.66	0.009
Commissary, labor	1,500.00	
Supplies	6,067.37	
Total	$ 7,567.37	0.010
Repairs, labor	$ 535.75	
Material	1,390.10	
Derrick	951.59	
Total	$ 2,877.44	$0.004
Towing, "Richard B."	$ 2,377.16	
"Keystone"	5,512.06	
"Hausler"	11,455.41	
Total	$19,344.63	$0.026
Miscellaneous:		
Teams	$ 65.33	
Insurance	4,101.53	
Motor boat	363.37	
Scow service	270.42	
Pile driver	245.38	$0.007
Total	$ 5,046.03	$0.007
Total operation	$79,213.78	$0.107

Repairs

Labor	$ 7,057.58	$0.010
Material	5,746.50	0.008
Fuel	468.75	0.0006
Supplies	171.25	0.0002
Commissary	826.24	0.0011
Dunham tug	76.00	
"Richard B."	485.59	
"Keystone"	174.07	
"Hausler"	201.63	
Total	$ 937.29	$0.0012
Miscellaneous teams and pile driver	147,55	
Derrick	$ 357.46	
Total	$ 505.01	$0.0007
Grand total, repairs	$15,712.62	$0.022
Total operation and repairs	94,926.40	0.129

During the season no repairs involving any extended loss of time were necessary. There was no loss of time due to the main pump and only 2¼ hours on account of [illegible] the main engines. A short connecting section of cas[illegible] the discharge was worn through and repl[illegible] The cast steel pump casing and elbows [illegible]

The pontoon pipe was lined [illegible]ing

covering the bottom third of the pipe. This ⅜-inch sheet was worn and was replaced for the 1912 season's work. The rubber sleeves joining the sections of the discharge pipe gave fairly good service. The average life of a sleeve was 41 days; but eliminating those sleeves which were damaged due to the condition of the pontoons, the average life of a sleeve was 54 days. The cutter blades required to be renewed each year.

Cost of Dredge. The following table gives the list of items which together make up the cost of the dredge as it was put in operation in 1910:

Engineering, plans, inspection, etc.	$ 9,816.45
Contract (1907) with 2,000 ft. pontoons	151,402.19
Terminal pontoon scow (1907)	1227.88
8 Jones underfeed stokers (1908)	6,700.00
6 Pontoons (1908)	10,485.00
Miscellaneous	874.04
Total	$180,505.56

COST OF TENDERS

A motor boat costing $1,150 was used for transportation of the men, etc. One hundred and forty-six days of its time, at a cost of $4.00 per day, were charged to the dredge.

A hydraulic dredge was employed in the harbor improvements at Wilmington, Cal. The following statement shows the cost of dredging from April 1 to June 30, 1905:

Routine office work, labor	$ 673.33
Care of plant and property, labor	180.00
Surveys, labor and supplies	155.63
Towing and dispatch work, labor, fuel and supplies	316.00
Alterations and repairs to dredging plant, labor and material	2,432.52
Operating dredge, including superintendence and labor charges, fuel, fresh water, lubricants, and all other supplies	10,084.54
Deterioration of plant and property, estimated	2,263.94
	$16,105.96

Cost per cubic yard, $0.0708.

In addition to the hydraulic dredge, the following auxiliary floating plant is employed: A gasoline launch, length over all 30 ft. 1½ in., 7 ft. beam, depth 3 ft. 7 in., propelled by a 16 hp. "Standard" engine. Also nine pontoons, each 35 ft. x 10 ft. x 3 ft.; 15 pontoons, each 21 ft. 3 in. x 10 ft. x 3 ft.; one water boat, 34 ft. 9 in. x 10 ft. x 4 ft. 6 in.; one oil boat, 34 ft 9 in. x 10 ft. x 4 ft. 6 in.; one derrick boat, 29 ft. 6 in. x 10 ft. 7 in. x 3 ft. 10 in. The original cost of the dredging plant was as follows:

20 inch suction dredge	$ 99,453
Gasoline launch	1,733
Discharge pipe line for dredge	3,023
Rubber sleeves	1,275
Pontoons and barges	6,501
Skiffs	154
	$112,139

On the Chicago canal two dredges were used, which are described in *Engineering News*, September 6, 1894. Each dredge was equipped with a 6-inch centrifugal pump and a 250 hp. engine. The discharge pipe was 18 in. in diameter, made in 33 ft. lengths, coupled with rubber hose held by iron clamps. Each dredge averaged 1,732 yards in 10 hours.

Fig. 141. 20-inch Hydraulic Dredge Designed and Equipped to Work on New York State Barge Canal. This Dredge Has Delivered 456,000 Cubic Yards in One Month and Cost $76,000, Not Including Pipe Line or Pontoons.

In *Engineering News*, October 30, 1902, Mr. John Bogart, in charge of the Massena (N. Y.) canal, gives the cost of operating two dredges. Dredge No. 1 cost $40,000. It had a 12-inch wrought iron discharge pipe, a rotary cutter, and a centrifugal pump driven by a Lidgerwood compound condensing engine of 125 hp. It lifted the material 30 feet above the water and discharged it through a 2,000-foot pipe. The depth of cut was 22 feet below the water surface. The output averaged 1,125 yards in 22 hours, at a cost of $95.80, or 8½ cents per yard. Dredge No. 2 cost $60,000. Its discharge pipe was 18 inches in

diameter. The output averaged 1,554 cubic yards at a cost of $145, or 9.4 cents per yard.

Engineering and Contracting, May 15, 1918, gives the following on the construction of 18,000 ft. of 42 ft. top width, 21 ft. high embankment by the hydraulic dredge method. The approach embankments to the Columbia River Interstate bridge were constructed by the hydraulic dredge method. The embankments have a total length of about 18,000 ft., an average height of about 21 ft. and side slopes of 2 to 1. The Hayden Ave. embankment 1,480 ft. long and the main approach to Union Ave. are 42 ft. wide on top. The embankment of the secondary approach to Derby St., 5,800 ft. long, has a top width of 40 ft. The Vancouver approach embankments, total length 500 ft., have top widths conforming to the streets occupied.

The embankment for the Union Ave. approach, having a total net volume of 821,000 cu. yd., was placed in 160 days or at the rate of about 5,000 cu. yd. per day. The material was excavated from the Oregon Slough by means of a suction dredge with a cutting head and was transported to place by being pumped through a line of pipe 24 inches in diameter. The operation was by electric power and the main pump on the dredge was operated by two 500 hp. motors. The pump was of capacity to give a discharge through the 24 inch pipe at a velocity of from 12 to 15 ft. per second. Operations continued 24 hr. per day during the time specified and the dredge was actually running about 14 hr. per day. For periods of a few hours at a time the dredge pumped as much as 1,000 cu. yd. per hr. There was of course a very considerable run-off of sand from the embankment, as well as a certain amount of fine material which flowed away with the waste water, and it is estimated that about 250,000 cu. yd. more than the above net amount was transported. The discharge pipe line was extended to a length of about 5,500 ft. working from the dredge alone. For greater distances a booster pump was installed in the line to give greater impetus. This pump was operated by a single 1,000 hp. motor operating with considerable overload. The dredge and booster pump together transported through a maximum length of 9,000 ft. of pipe. Such long distance dredging into an embankment so comparatively narrow and high is believed to mark a record for work of this character. The pipe was of the ordinary riveted variety with slip joints made of 7 gage material on the pontoons and of 10 gage material elsewhere. It was moved about by teams and wagons.

The embankment was formed by the use of timber bulkheads. These were built of 6 by 8-in. posts, about 10-ft. centers, supporting 2 by 12-in. sheathing, surfaced both edges. The sides of the

embankment were built up by these means in steps 8 ft. wide and 4 ft. high. The first bulkheads were placed upon the natural ground surface by driving in the 6 by 8-in. posts with a hand maul and setting the lower plank into a small trench so that the bulkhead sheathing extended perhaps 8 to 12 in. below the ordinary ground surface. When the sand had been filled in about the top of such first bulkheads, posts for succeeding bulkheads were set in place and the lower plank placed so that it extended about 12 in. below the top of the first bulkhead below. These posts were tied back into the embankment by 2 by 6-in. ties spiked on near the top of each post and extending back to a short post, in front of which were placed a few pieces of lagging to offer additional resistance. The pipe was laid to discharge into the middle of the embankment and was carried forward from the river, bringing the embankment up to the final grade and working away from the dredge. A framework of baffleboards was placed under the discharging end of the pipe, causing the water to spread out and spill over the ground below and run forward, distributing the different sizes of material as the velocity decreased. At some convenient low point there was provided an outflow down the side of the embankment for which the steps of the embankment were paved with plank to prevent wash.

The methods of constructing the bulkheads and of the discharge arrangement are shown by the accompanying illustration. After sections of the finished embankments became thoroughly drained as the work proceeded, the posts of the bulkheads were cut away and the planks removed and carried forward for repeated use. Parts of the posts and of the 2 by 6-in. ties therefore remain in the embankment. The finishing of the slopes was done by hand with shovels, and the successive steps were so located that the upper corner of each step filled into the lower corner of the step below, to provide the proper slope. The actual pumping and transportation of the sand in the hands of the contractors were the simplest parts of the work, and they found it economical to permit a very considerable wastage of material where such wastage saved in the construction of bulkheads.

The secondary approach to Derby St. was constructed in a similar manner by an electrically operated suction dredge with 20-in. diameter pipe equipment. The maximum distance the material was carried was about 6,500 ft. This embankment contained about 515,000 cu yd.

The embankments were constructed by the Tacoma Dredging Co., the unit price for the Hayden Ave. and Union Ave. approach being 13.24 ct. per cubic yard; the price for the Derby St. approach was 16.48 ct. per cubic yard. J. L. Harrington and E. E.

Howard were Consulting Engineers for the bridge. The matter given above is abstracted from their final report.

Selection and Operation of Dredging Equipment. The following notes have been abstracted from a reprint of some admirable articles in *Engineering Record* which were called to the attention of the author by the writer. Mr. Shaw's notes on the handling of dredges should be read carefully by every one undertaking work of this character. Certain well-developed types of dredges will work economically under a considerable range of conditions, but there is no one machine which is best suited to all, or even to most conditions.

This discussion of various types of equipment and the power plants used to operate them is confined principally to those used in the reclamation of lands in the lower Mississippi delta. The types considered are dipper dredges, orange-peel and clamshell dredges, hydraulic dredges and dragline dredges.

In a number of cases moderately large dredges have been moved intact over considerable distances across land, but the writer has yet to learn of any individual owner who has made such an experiment and who is ready to attempt it a second time.

The greatest variation in the details of floating dipper dredges is found in the types of spuds used, in the manner of raising and lowering the spuds and in "pinning up." There are two general types in common use — the vertical and the bank spuds. Vertical spuds are comparatively simple, are adaptable to a wide range of depth and are independent of the width of canal. They are usually raised and lowered by independent engines, either by means of cables or by compound gears engaging a heavy rack which is attached to the spud. Cables are now quite generally preferred, though the rack is still in common use and is preferred by some. Neither type has any marked advantage in the matter of simplicity. The cable system has one considerable advantage in that it permits setting the engines farther aft, where they can be more easily attended to by those having the care of the main engines.

The power for raising spuds on some dredges is compounded by means of worm gears, but the writer considers a worm gear a necessary evil, to be tolerated on some machines but never on a dredge.

Bank spuds give greater stability to the hull, being, as their name implies, set out on the berm or bank. They permit the use of a much longer boom on a dredge of given width than is possible by the use of vertical spuds. On some machines the bank spuds act as an outward support, the strain being carried

to the hull by a well-braced structure acting as a beam. In other cases the strain is transferred direct to the top of the A-frame. That portion of the spud which rests on the bank is in the form of a plank platform, and for work in soft material these platforms are extended so as to cover a considerable area. In some cases these platforms are hinged along the center so that they may be more easily raised out of sticky material. One of the principal objections to bank spuds is that they often crush down the berm, inducing slides in the levee or waste bank. It is impracticable to use bank spuds in wide canals or open water of any considerable depth.

Owing to the powerful thrust of the dipper acting in various directions, the rigid bracing of spuds and fastening of all spud connections, whether of the vertical or bank type, are most important.

Comparison with other types of dredges is most favorable to the dipper type when working in hard, compact material such as cemented gravel and ledge rock. It is usually preferred for digging through heavily timbered country, especially through trees having large tap roots. Its ability to bring a tremendous amount of power to bear at a single point contributes to its popularity in heavy timber work. Whenever possible, however, all large stumps should be loosened and shattered before the dredge reaches them.

Dredges are designed for handling earth, and there is no economy in delaying and overstraining them in grubbing stumps when it is reasonably practicable to remove, or at least loosen, the stumps by other means. In soft ground, blowing stumps entirely out of the ground should not be attempted, as the ground beneath them does not afford sufficient resistance to make this possible without an excessive cost for dynamite. A better plan is to bore a hole into the stump and place the explosive where its shattering effect will be the greatest.

Hard gravel and rock should be blasted ahead of the dredge even though it may be possible to make some progress without first loosening the material. Dipper dredges equipped with crowding engines on the boom and with special teeth on the bucket will make fair progress without preliminary blasting in soft limestone rock which is in fairly thin layers. It will usually be found more economical, however, to do some preliminary blasting in all such material.

Loss of time frequently occurs in the use of a dipper dredge by the jamming into the bucket of a large stump or boulder, though a skillful operator will seldom permit this to occur.

In mucky soils dipper dredges often disintegrate the material to such an extent that much of it is carried in suspension in

the canal for several hours, to be deposited later in the bed of the canal and materially reduce the section. In the very soft trembling prairies of southern Louisiana this will occur to a certain extent with any type of dredge, but is most noticeable with dipper and dragline machines, which require a long movement of the bucket in filling.

Variations in mounting and methods of moving are much the same with grab-bucket dredges as with the dipper type. Spuds are usually cable-operated. The spuds are used as anchors only, since there is less necessity for pinning up a dredge with this class of machinery. For levee construction and other classes of work on which the bulk of the material is to be dumped to one side of the excavation, gravity swing outfits are preferred on account of their simplicity, low first cost and economy of operation.

Orange-peel and clamshell buckets are most efficient in handling gravel, sand and soft material, though boulders, pig iron and blasted ledge rock are handled economically by the larger, three-bladed orange-peels of extra-heavy construction. In hard, packed sand the clamshell is most suitable, as it gathers its load by the scraping action of the blades. In hard digging teeth are placed on the edges of clamshell buckets for loosening the material. Though, owing to the large number of wearing parts, repairs are frequently required with grab buckets, they are readily made, usually by the substitution of small bushings and pins. A liberal supply of these repair parts should be kept in stock. It is usually found most economical to keep an extra bucket on hand so that at least one may be in perfect condition at all times.

Orange-peel buckets are preferred to clamshells for digging stumps, widening canals and other work where it is necessary for the bucket to fill on irregular surfaces or grab hold of materials of varying density. For digging stumps other than those having large tap roots the orange-peel dredge of large size is fully equal to any other type. Its ability to dig on all sides of a stump, tearing loose each individual main root, makes up for its lack of the great lifting and shoving power of the dipper dredge.

While not well adapted to digging hard sand, the orange-peel bucket may be used in such material with moderate success if properly handled. To insure economical loading the bucket should be dropped into the pit in a partly closed position, the blades being held as nearly vertical as practicable. After dropping, the closing line should be overhauled slightly and released, repeating this operation as many times as may be necessary to load the bucket. It is not usually feasible to secure a full load by this method, nor is this desirable, as the "suction" in such

material is so great that it is almost impossible to break loose with a full bucket of packed sand.

Though careless manipulation of dredges of any type when working in soft muck will stir up the material in much the same manner as will a dipper dredge, grab buckets, if intelligently handled, will excavate such material much better than any other bucket dredge. When working in material easily carried in suspension by the water, the bucket should not be permitted to bury itself in the bottom of the canal, but should be held by the "standing line," so that it will load with only such material as it can take out of the canal. Overloading and consequent dropping of broken material back into the water is the cause of most of the loss in section through sedimentation of canals dug by grab buckets. In cleaning out old canals which have become partly filled with fine ooze especial care is necessary to insure tight closing of the bucket. In the tough muck and Sharkey clay which are typical of the lower Mississippi delta grab buckets may be loaded 30% to 40% beyond their rated capacity without danger of any considerable portion of the load dropping off.

Until quite recently most of the river levees on the lower Mississippi were built by wheelbarrow or team work. These methods are now largely superseded by land dredges and by tower and cable rigs, though a few floating dredges are also used. As the material for building these levees is taken from the river side and land equipment cannot be operated excepting during moderately low stages of the river, the working period is reduced to a few months of each year. It would seem as though, by making a slight modification in the specifications for the construction of these levees, it would be possible to use floating dredges with extra-long booms for a large portion of such work.

It is seldom that a dragline dredge is mounted on a barge, as its operation tends to form a mud roll ahead of the bucket which cannot easily be removed excepting as the machine backs away from its work. Dragline machines are moved on rollers, trucks or caterpillar treads. The "whirler" type is usually preferred, as it can reach back for sections of track which have been passed over and transfer them ahead. An excellent type of track for a heavy skid excavator operating on soft ground is described by D. W. O'Bannon in the *Excavating Engineer* for July, 1916.

The dragline machine has a marked advantage over other types in that it can handle a larger bucket for a given power unit than any other bucket dredge. Little if any lifting force is required while the bucket is filling, and the power for loading is applied in nearly a direct line from the winding drum, thus making it possible to exert practically the entire power of the engine in filling

and cutting through obstructions. The dragline embodies many of the advantages of both grab-bucket and dipper dredges, with some of their disadvantages, as well as some peculiar to itself. It can dig around a stump in much the same manner, though not so well, as an orange-peel and can bring great power to bear at a single point in an effort to overturn the stump. Large stumps cannot be lifted clear of the pit without the use of chains, and in making an extra hard pull there is always present the danger of overturning the machine or of pulling it from its supports.

These machines will handle almost any material that can be excavated by a dipper dredge. *They are not well adapted for digging soft material which washes easily.* The stirring action is much the same as that of the dipper dredge and the bucket is not so well able to retain the material. Observation of a dragline machine engaged in excavating material deposited by a sluggish current in an old canal showed that the bucket was taking out only about 30% of its rated capacity at each load. In suitable material, however, it will load considerably beyond the rated capacity. Under skillful manipulation a dragline machine is capable of dressing off a levee much better than can be done by any other type of bucket machine.

Hydraulic dredges are often preferred for interior canal construction on account of their ability to spread the excavated material over a wide area, thus avoiding wasteful and unsightly banks. They are not often used for levee building on reclamation projects, though they have been so employed with good results. The preferred method in cutting new canals is to make a first cut with a small bucket dredge, dumping the material in about equal quantities on either side, to form a barrier which prevents the material excavated by the hydraulic dredge from flowing back into the canal. In other cases a small hand-built levee serves the same purpose. A levee or ridge of sod 2 ft. in height will usually retain the discharge from a 12-in. hydraulic dredge, provided the point of discharge is 30 ft. or more beyond the levee. For canals having a section much in excess of 10 yd. per linear foot a larger levee will be required.

Suction dredges are subject to delays through the stoppage of suction pipes and pumps from grass, roots and other débris, though the larger sizes are seldom troubled by anything smaller than stumps. Nothing less than a 10-in. pump should be used for work of this class, owing to frequent stoppage of the suction line, while the very large sizes are usually unsuitable because they require so large a hull that they cannot be used in the smaller canals. A 12-in. dredging pump with all necessary equipment can be mounted on a barge 24 x 80 ft, which will be found

suitable for digging 30-ft. canals — a common size for the smaller systems. A 12-in. pump, equipped with a suitable cutter, will pass a surprising amount of solid articles. In cleaning out the Chalmette slips below the city of New Orleans a solid cannon ball from the Chalmette battlefield, pieces of ship's rigging and various other bric-à-brac were brought out by the suction dredges.

The greatest variation in these dredges is found in their cutter heads, their design and speed of rotation being dictated by the character of the material excavated. In hard, gravelly material a rugged cutter head is required which will produce the maximum agitation in the material. In the muck and soft clay soils of the lower Mississippi delta, on the other hand, a slicing action of the blades secures better results, especially if combined with only moderate speed of rotation.

The effective work of a hydraulic dredge depends to a great extent on the percentage of solids discharged. This percentage will drop with a dull, sickening thud if the dredge is operated carelessly or if it is not equipped so that the cutter head may be kept close up to the work and so regulated that it will not clog. In deep excavations care must be used to prevent undercutting to such an extent that heavy material can drop down onto the ladder and cutter head and choke the pump or wreck the end of the ladder.

Hydraulic dredges for canal excavation should be equipped so that they will discharge normally through a Y connection on both sides of the canal. The point of discharge should be not less than 50 ft. beyond the side of the hull, the pipes being supported by gallows frames or A-frames with cables. Each discharge should be equipped with a valve so that it can be closed temporarily for passing obstructions or intersecting canals. Where growing crops or other improvements do not prohibit the discharge of water and mud over adjacent lands hydraulic dredges are preferred to any other type for cleaning out old canals which have lost much of their original section through sedimentation.

Suction dredges may handle stumps by first undermining and then dragging them out with a line from a winch head on board the dredge. Although stumps may be taken out in this manner this type of dredge cannot be operated economically in a heavily timbered area.

Most of the power problems in dredge operation and design are common to all the classes of equipment described. Heretofore steam power has been used almost exclusively, the smaller dredges being equipped with the simplest type of slide-valve hoisting engines. Hydraulic dredges have usually employed a better grade of engine in their main power unit.

Great difficulty is experienced near the coast in securing suitable boiler-feed water. The unlimited use of raw water from the canals results in expensive delays and repair bills through the rapid deterioration of boilers, steam piping and engines. This trouble is reduced, though not eliminated, by the use of condensers. A dredge equipped with a complete salt-water outfit, including condenser, circulating and vacuum pump and a high-speed evaporator, was constructed by the writer in one instance for use in waters which were exceptionally bad. This plant has now been in nearly continuous operation for three years with no serious delays from the steam end of the outfit. Although the steam auxiliaries cost nearly the same as the boiler itself, it appears by comparing the operation of this dredge with that of others operating in the same water, but not similarly equipped, that the extra equipment has paid for itself several times over.

The intermittent but frequently excessive demands for steam on most types of dredges makes it necessary that an ample capacity for producing dry steam should be provided. Condensers, evaporators and steam separators are an aid, but nothing will fully make up for a deficiency in boiler capacity. Foaming, due to overcrowding the boilers, especially when supplied with poor water, reduces the available power of engines, carries away the lubrication and contributes to a large extent to engine breakdowns.

Another factor in limiting the power supply is curtailment of draft through the unnecessary abbreviation of the stack. There is no reason why the average floating dredge should not carry a smokestack more nearly approximating the length established as good practice in other lines of steam engineering. In spite of this fact it is not uncommon to see an 80 or 100-hp. dredge boiler supplied with a 20-ft. stack. The design of the stack, however, should be based on the coal burned per hour rather than on the rated horsepower of the boiler, which should be considerably in excess of the theoretical requirements.

The accompanying table illustrates the writer's ideas as to suitable proportions for a 1½-yd. orange-peel, gravity-swing

Suitable Proportions for 1½-Yard Orange-Peel Dredge with 50-Foot Reach

Width of hull	36 ft.
Length of hull	80 ft.
Depth of hull	6 ft.
Length of boom	75 ft.
Spread of main drums	16 ft.
Double-cylinder main engine	10 x 12 in.
Boiler	80 hp.
Diameter of stack	27 in.
Height of stack	50 ft.

dredge designed for a given reach of 50 ft. from the side of the excavation. These proportions contemplate setting the machinery down in the hull. If set on deck, it would be advisable to increase the diameter of stack to 30 in. and reduce the height to 40 ft. Such an outfit should operate on about 300 lb. of coal per hour.

Gravity swing dredges may be operated satisfactorily by single, constant-speed engines, the speed of hoisting lines and other operations being regulated by the slipping of friction clutches. The control of hoisting speed by the slipping of frictions is considered by many as wasteful and unsatisfactory, but with a properly designed device it has been found satisfactory, especially on machines of moderate size. For such service, the friction blocks should be of generous dimensions and turned true so that there will be complete contact over a large area. Maple seems to be preferred for friction blocks by manufacturers of dredging and hoisting machinery, but the writer has secured better results at a smaller cost by using well-seasoned black gum. Any good pattern maker can turn out a satisfactory set of blocks if given an accurate set of drawings to work from. A small gravity swing dredge has been operated from a constant-speed, internal-combustion engine for a period of over three months without renewal of the black gum friction blocks used in controlling the main hoisting drums.

SECTION 34

DRILLS

Hand Hammer Drills adapted to work in hard rock on excavation jobs of all kinds where holes are to be drilled downward either vertically or at an angle, except where very deep holes or those of large diameter are required, are illustratd by Figs.

Fig. 142. Hand Hammer Drill, Sullivan "Rotator."

142 and 143. In addition to their use for general rock excavation, these drills have a wide application in demolishing old masonry, breaking up concrete, removing pavement and kindred jobs for which service they effect a saving over hand work. On many jobs hand hammer drills have demonstrated their ability to

turn out more work than mounted drills due to the fact that no time is lost in setting up and moving tripods.

All self-rotating hand hammer drills require hollow drill steel

Fig. 143. Hand Hammer Drill, Ingersoll-Rand "Jack Hammer."

and may be had with either an air jet device or with a device feeding both air and water to the bottom of the drill hole to free

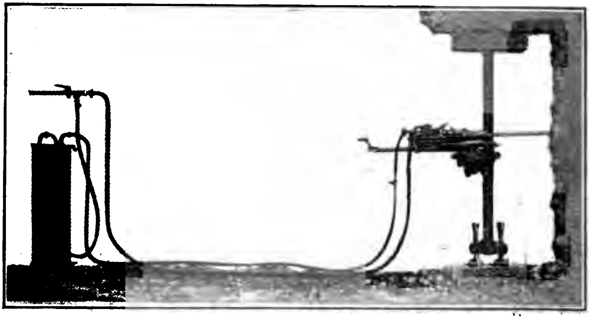


Fig. 144. Mounted Hammer Drill. Leyner-Ingersoll Type Set Up on Column with Arrangement when Water Tank Is Used.

it of chips. The dry type is the accepted standard for outdoor work, and the water feed, or "wet" for use in underground excavation.

The prices are as follows:

Depth tool will drill in feet	Weight in lb.		Price Wet	Price Dry
6	30	air		$170
10	38	air	$195	170
10	38	steam	195	170
12	40	air or steam	195	170
..	75	air	275	250

Fig. 145. Air Feed Hammer or Stope Drill Fitted with Dust Allayer.

Mounted Hammer Drills adapted for use in tunnel driving and mining are operated with a tripod mounting where the drilling is downward and a column or bar where the drilling is horizontal. They are illustrated by Fig. 144 and are generally of the water feeding type, employing hollow drill steel. For their work capacity they are lighter than the reciprocating type of drill. The price without the mounting is as follows: $300 for the light type weighing about 100 lb.; $360 for the heavier type weighing about 160 lb. These drills are operated by air only.

Air Feed Hammer Drills or stope drills generally used in mining may also be used in trimming the roof of a tunnel. They

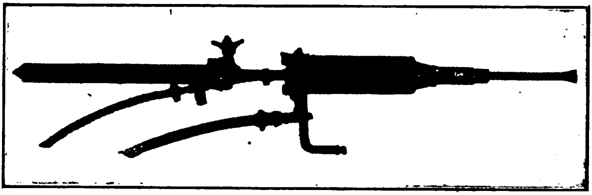


Fig. 146. Sullivan Rotating Water Stoper.

are designed to work at an angle above the horizontal. One make may be had in two types; the dry weighs about 85 lb. and costs $200; the wet type weighs about 90 lb. and costs $225.

Another make costs as follows: automatic feed, dry type $275; wet type $300; both of these weigh about 120 lb. Hand feed, dry type $200; wet type $225; both of these weigh about 85 lb.

An attachment for use in allaying the dust from the cutting is illustrated by Fig. 145 and consists of an attachment on the drill with a connection to the air supply and a bucket or other receptacle for the water. This attachment costs $10.

Mounted Piston Drills used in quarrying and open cuts are mounted on either a tripod or quarry bar. They may be operated on either compressed air or steam. The cost as follows:

Diameter of piston in in.	Approximate weight in lb.	Price f. o. b. factory
2½	190	$235
2¾	268	265
3	278	275
3¼	350	298
3½	390	330

Electric Air Drills. Some of the conditions that particularly favor the selection of this type of drill are as follows:

(1) High altitude, which impairs the efficiency of the ordinary compressor.

(2) Long transmission lines, wire being cheaper than pipes.

(3) Cheap electric power, of the right voltage and frequency.

The electric air drill is driven by pulsations of compressed air caused by a "pulsator," which is driven by an electric motor. The air is not exhausted, but is simply used over and over again, working backward and forward in a closed pneumatic circuit, from which some leakage of air is necessarily inevitable. This leakage is provided for by compensating valves on the pulsator, adjusted to automatically maintain a constant average

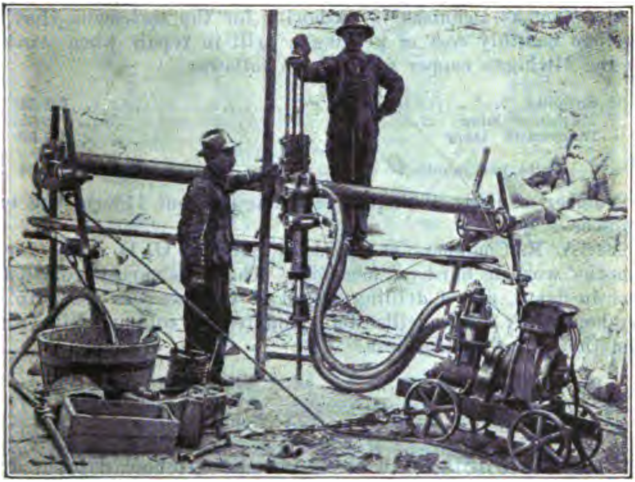


Fig. 147. "Electric Air" Drill at Boutwell Milne and Varnum Quarry, Barre, Vt.

pressure in the circuit. The drill is practically a cylinder containing a moving piston and rotation device, without valves chest, buffers, springs, side rods and pawls. The cylinder is larger than that of the corresponding air drill, but the piston is shorter, thus involving no great difference in weight between this and the older types. The pulsator requires no intake and discharge valves nor water jackets. It is geared to a motor which may, of course, be of either direct or alternating current, and is mounted on a wheeled truck for convenience in handling. The pulsator and drill are connected by two short lengths of hose, each of which acts alternately as supply and exhaust.

It is claimed by the manufacturer that with the electric air

drill there is far less loss of power than in the case of the ordinary air or steam drill, and this claim seems, on theoretical grounds, to be well founded.

Complete electric air drills average about $1,000 in price. Similar machines driven by a gasoline engine instead of an electric motor are also manufactured.

Drill Repairs. In the South African gold mines the cost of drill repairs was, in 1912, about $300 per drill per year, or 50c per shift for two-shift work, and the size of the average drill is about 3¼ inches.

Mr. Thomas Dennison is authority for the statement that the average monthly cost of keeping a drill in repair when working in the Michigan copper mines is as follows:

Supplies	$ 1.31
Machinist labor	8.45
Blacksmith labor	1.60
Total per month	$11.36

Number of drills in shop at one time is about 15% of the total number.

Mr. A. R. Chambers has used 25 Sullivan U. D. drills for 11 months' work in hard red hematite. The holes varied from 6 to 8 feet in depth, and a drilling record of 104 feet was made in one ten-hour shift. The drills were mounted on columns with arms, and the cost of repairs was:

Materials	$5.30
Labor	2.00
Total	$7.30

per month per drill, or about 30 cents per ten-hour day per drill.

Mr. Josiah Bond kept record of drill repairs for three years and they show a cost of $102, $101.50 and $93.75 per year per drill, respectively, for the three years. It is his opinion that a drill used night and day for one year is sufficiently worn at the end of that time to scrap and that its life for single shift work is three years.

Mr. Charles H. Swigert is authority for the following data on tunnel work in very hard basaltic rock. In 9½ months the total of 65,400 feet of hole was drilled, being an average of 29 lin. ft. of hole per drill. The drills were of 3-in. size. Cost of repairs for four drills was as follows:

Repairs	Per Lin. Ft. of Hole	Per Cu. Yd. Excavated
Labor	0.60 cents	2.80 cents
Material	1.40 cents	6.80 cents
Total	2.00 cents	9.60 cents

The total drill repairs amounted to 58c per eight-hour shift. In 9½ months 2,262 shifts were worked.

Mr. Hauer states that on one Ingersoll-Sergeant drill of 3⅜-in. size, class F, the repairs, not including repairs to hose, amounted to $5 per month for a period of four to five months.

I am indebted to Mr. John Rice, vice-president of the General Crushed Stone Co. of South Bethlehem, Pa., for the following information as to drill repairs:

No. of Drills.	Ingersoll - Sergeant Type Drills.	No. Ft. per Year.	No. days.	Average Ft. per Hour per Drill.	Max. Average per Hr. Each Drill.	Min. Average per Hr. Each Drill.	Repairs per Ft. Cents.
			Quartzite — 1904.				
9	F 9	101,379	1,525	6.65	7.03	6.12	*0.61
			Quartzite — 1905.				
8	F 9	118,597	1,383.5	8.57	9.25	7.55	†0.64
			Limestone — 1903.				
7	F 9	93,118	922	10.1	10.7	9.37	*.031
			Limestone — 1904.				
7	F 9	114,430	1,130	10.13	11.47	9.32	†0 56
7	F 9	107,837	913	11.8	12.69	10.0	†0.57
			Exceeding Hard Trap — 1905.				
5	F 9	36,973	1,411	2.62	3.05	2.58	†1.7
4	A 32	......	....	....	2.57	2.24	....

* Drill parts only. † Drill parts, steel and hose.

Note: The Ingersoll-Sergeant drill F 9 has a cylinder 3⅝ in. in diameter and a 7-in. stroke. The Ingersoll Sergeant drill A 32 has a cylinder 2½ in. in diameter and a 5-in. stroke.

Mr. Bond (quoted above) observes that a well-made heavy bar or column should outlast four drills, and arms are generally strong enough to finish three drills. He considers that repairs and depreciation on a stoping drill are about 50c per shift.

The cost of repairs to two Ingersoll drills 3⅛ inches in size at the Melones mine was $91.00 for over 2,600 feet of tunnel.

The following drill repair costs are given in "Rock Drilling," by Dana and Saunders:

The cost for putting in shape for work nine drills on the D., L. & W. cutoff was $1,100. Repairs on fourteen drills for the first 13 months after the commencement of the work amounted to $695.62, or an average of $3.80 per drill per month, or 38 cents per drill per shift.

At Thornton, Ill., the repairs on fourteen drills during nine months in 1909 cost $3,058.47, or 93 cents per drill per day, single shift work.

The foregoing costs of drill repairs are all prior to 1912.

Drill Sharpening Machines. These machines are illustrated by Figs. 148 and 149. A machine weighing 4,400 lb. for shipment costs $1,225 without dies or dollies. Another make comes in three sizes, 2,150 lb. costs $1,200, 1,700 lb. costs $900 and a

Fig. 148. Leyner Drill Sharpener.

small machine for bitting and shanking weighs about 925 lb. and costs $600. All the foregoing prices are f. o. b. factory.

Complete sharpening shops generally have included in their equipment a punch for opening a hole in hollow steel after sharpening and shanking and a grinder for dressing drill shanks and light grinding. Both of these machines are air operated.

One drill sharpening machine was operated by one man who attended his own forge and made necessary repairs. It ran on an average of 4 hours per day and sharpened approximately 36,000 drills, averaging 50 drills per hour. The amount of fuel

used was about one-half that required in hand work. To form and sharpen new drills required 1½ minutes. The life of a bit sharpened by this machine is longer than when done by hand, the bits being better compacted, and drills can be sharpened at the same machine by the same dies. Before this machine was used two blacksmiths and two helpers were necessary, the machine showing a saving over hand labor in 6 months of $1,738.50 and saving in coal for 183 days, $83. Total saving for 6 months, $1,821.50. (No record as to machine cost.)

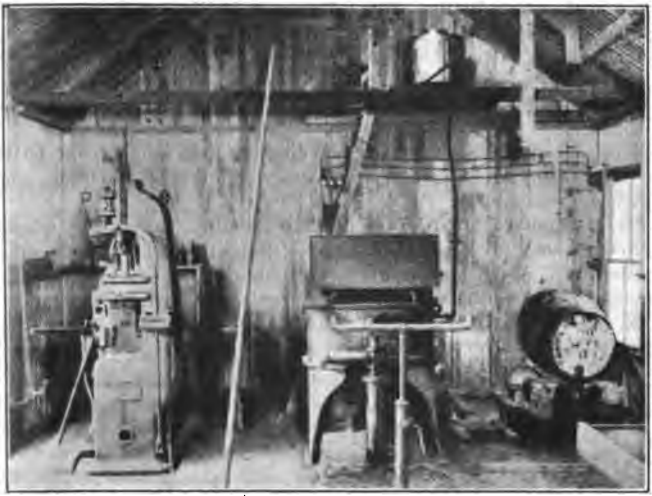


Fig. 149. Sullivan Sharpener on a Tunnel Contract in Arizona.

In the South African gold mines each drilling machine uses an average of twenty drill points per shift, which amounts to 600 lb. of drills removed to and from the job for each machine per shift. One blacksmith with a helper will keep 5 to 7 drills supplied with sharp bits. In medium rock a bit must be sharpened for each 2 ft. of hole, in hard rock, for each 1½ ft., and in soft rock for each 4 ft. The direct cost of sharpening bits by hand is about as follows:

Blacksmith	$3.00
Helper	2.00
Charcoal	.60
Total (1912 figures) ....140 bits at 4 cents =	$5.60

Mr. T. H. Proske says:

"The power drill-sharpener has removed many of the shortcomings attendant upon the hand sharpening process, with the result that where these machines are used it is possible to accomplish from 25% to 100% more drilling than under the old methods." I take this to mean 25% to 100% more drilling per trip to the shop on the part of the drill tender, which statement is well within the facts. Especially is this true when the machine sharpening is combined with the selection of special drill steels.

Hand Hammer Drills. Hand Hammer Drills are light, powerful, small tools which are adapted to light work in mines and quarries.

These drills cost about $65. Drill steel in small quantities costs about 20c per lb. for the hollow and about 13c per lb. for the solid.

Riveting hammers cost from $90 to $100 and weigh from 15 to 30 lb. Scaling and chipping hammers weigh from 7 to 15 lb. and cost from $50 to $70.

Performance of Small Hand Hammer Drill. The author examined with some care the operation of a small hand hammer drill in the field operating in granitic schist in a New Hampshire quarry. The operation of changing steels required an average of 11⅕ seconds on the part of a highly skilled operator. The field notes of this test were as follows:

	Time: Hours	Minutes	Seconds
Start of first steel	1	42	3
Finish of first steel	..	43	25
Start of second steel	..	43	37
Finish of second steel	..	44	54⅗
Start of third steel	..	45	5½
Finish of third steel	..	46	20
Start of fourth steel	..	46	31⅗
Finish of fourth steel	..	47	20⅕
Start of fifth steel	..	47	13⅘
Finish of fifth steel	..	48	22½

Total depth of hole, 55⅛ in.
Average depth per steel, 11 in.
The steel used was ⅞-in. hexagonal hollow rolled steel.
First bit, diameter, 1¾ in.
Last bit, diameter, 1¼ in.

After the hole was finished, dust filled the hole to about a depth of 8 in. until blown out, which time for blowing out is not included in the above time study. The elapsed time for the entire operation was 6 min. 19⅕ sec., or 6.32 min. The total time to change steels was 44⅘ sec., or .75 min., making 5.57 min. for drilling time, or practically 10 in. per minute. This, of course, did not include the time of getting ready for a new hole

or blowing out the old hole, both of which operations could easily be accomplished in 30 seconds by an average operator. This example is given to show the adaptability of these small hand machines for rapid and economical work on comparatively shallow holes. In addition to the air pipe is shown a pipe running to the pressure gauge, which registered 102 lb. when the drill was not working and 85 lb. with drill running. The former pressure represented the pressure at the compressor. In this drill some of the exhaust goes down through the bit and blows the rock cuttings up out of the hole, producing a heavy cloud in a strong wind.

SUBMARINE DRILLS

There are two general methods of submarine drilling: (1) "Platform Method," so-called from a platform or staging supported on "spuds." This method is applicable where currents are excessively disturbing influences. (2) The "Barge Method" employs a floating scow or barge carrying the drills and other equipment, anchored in place by cables or chains. The height of the framing, length of feed, etc., and resulting price of equipment, depend upon depth of drilling.

A number of plants for subaqueous drilling are described in "Rock Drilling," by Dana and Saunders, from which the following data are abstracted:

The Platform Method. Cylindrical telescopic tubes with a conical taper, fitted with an ejector attachment, rest on the rock, with upper end above the surface of the water. Drilling, washing and charging are performed through these tubes. The use of the water jet is usually very economical. The boilers, shops, pumps, diving apparatus, etc., are usually carried by barge or scow moored to the platform and by anchors.

In the operations on Black Tom Reef, New York harbor, which commenced May 2, 1881, 344 actual working days were occupied in drilling 1,736 holes, a total of 17,658 lineal feet (av. depth 10.17′) and removing 5,136 cu. yd.

The cost of plant, including alterations and additions, was as follows:

Barge No. 4, hull and equipment	$ 6,640.00
Drill Float, No. 1	4,095.70
Drill Float, No. 2	4,987.40
Machinery, etc.	3,815.51
Total	$19,538.61

The foregoing cost of plant and the following cost of operation are excessive, due to the experimental work prior to the introduction of the improved methods of operation.

The operating expenses were as follows:

	Total Cost	Cost per Lin. Ft. Drilled	Cost per Cu. Yd. Removed
Labor	$ 9,203.88	$0.521	$1.792
Explosives	9,461.00	0.535	1.844
Actual repairs to plant	1,575.57	0.089	0.307
Repairs to drills	93.31	0.005	0.018
Repairs to ejector pipes	267.54	0.015	0.052
Steam and water hose	491.18	0.028	0.096
Connecting wire, 77¼ lb.	52.08	0.003	0.010
Rubber tape for connections, 7 rolls	12.25	0.001	0.002
Water	500.55	0.029	0.096
Coal, 200.2 tons	823.03	0.047	0.160
Total (1882)	$22,480.39	$1.273	$4.377

Area drilled over	32,100 sq.ft.
Dynamite used	20,461 lbs.
Exploders used	1,844
Number of drilling machines	3
Steels used (octagon 1½")	18
Total loss of steel by abrasion and dressing (59.5')	394.5 lbs.
Average depth of hole to each cu. yd. rock removed	3.44 lin.ft.

Barge Method. The drill boat used by the Great Lakes Dredge Dock Co. at West Neebish Channel, St. Mary's River, in 1909, was of timber, 126 ft. long by 30 ft. beam, covered by a house in which were boilers, shops and men's quarters. The equipment included the following:

1 Scotch marine (3 fire) boiler, 14' long x 13' diameter.
1 Each blacksmith's forge, anvil, block with stack, bench, vise, pipe clamp.
17 Span drill bits.
1 Hydraulic cylinder, 12"x 15' 6" with 3½" piston and traction chain for moving drills.
1 Small feed pump.
2 Force pumps.
1 dynamo (and switchboard) driven by one cylinder belted engine; dynamo 110 volts and 42 amperes, D. C., 5 h. p., 1,600 r. p. m.
1 Small vertical washout boiler.
5 Drill machines, 6½" on track of 2' 6" I beams.
2 Steam driven capstans.
4 Spud engines, 6" x 6½".

The cost of the plant was approximately $35,000.00.

The drill boat "Earthquake" used by Dunbar and Sullivan on Section No. 3 of the Livingstone channel, Detroit River channel improvement, had a steel hull 106 ft. long, 30 ft. wide and 5 ft. 9 in. deep. The deck was of 2-in. planking, and the house, 89 x 19 x 13 ft. high, also of wood. The framework of the hull was composed of standard angles and brackets, and divided into four watertight compartments by transverse bulkheads.

The equipment includes the following:

4 Drills and equipment.
4 Spud anchors.
4 Spud anchor engines.
2 Steam capstans.
17 Bits.

Actual drilling labor per ft. of hole (cents)	Kind of Rock	Kind of Drill	Depth of Hole (ft. and in.)	Starting bit (inches)	No. of men to drill	Remarks.	Authority.
1.62	Sandstone	Steam	7–0	4¾	2	Great Lakes Dredge Dock Co., Boat No. 5	Dana
3.53	Limestone	Steam	10–6	4½ & 4	2	West Neebish Channel "Exploder"	Dana
4.42	Sandstone	Steam	6–0	4½	2	Edwards Bros.' Boat	Dana
4.50	Limestone	Steam	11–0	4	2	"Dynamiter"	Dana
4.86	Limestone	Steam	8–0	3½	..	Buffalo Boat No. 5	Dana
5.30	Limestone	Steam	14–0	3½	2	"Earthquake"	Dana
5.58	Limestone	Steam	12–1	3½	2	"Hurricane"	Dana
6.53	Limestone	Steam	7–2 & 8–2	...	2	Buffalo Boat No. 4	Dana
6.96	Limestone	Steam	12–6	4½ & 4	2	"Destroyer"	Dana
6.98	Limestone	Steam	5–4	4½	2	Buffalo Boat No. 1	Dana
7.1	Coral	Steam	10–0	...	1 runner & ½ helper	Cienfuegos Harbor, Cuba	Gilbert
7.14	Limestone	Steam	10–1	...	2	Buffalo Boat No. 2	Dana
8.9	Soft Shale	Steam	6–2	2½	..	21′ Water, Detroit River	H. Hodgman
10.9	Limestone	Steam	8–2	2¼	2	18′ Water	H. Hodgman
9.3 to 17.63	Limestone and Flint	Steam	3–6 to 10–9	...	2	Black Rock Harbor	Gilbert
15.0	Limestone	Steam	5–6	2½	..	21′ Water	Hodgman
16.72	Hard Limestone	Steam	1–5 to 22–0	...	2	Hay Lake and Neebish Channel	Dana
18.4	Hard Limestone	Steam	Av. 6½′	...	2	Ship Channel, St. Lawrence	Gilbert
24.2	Gneiss, Quartz, Mica Schist	Steam	7–0	...	2	Oak Point, East River	Gilbert
24.7	Slate and Flint	Steam	5–0	...	2	Kennebec River	Gilbert

1 Hydraulic cylinder, 11 ft. long x 12 in. diameter for shifting drills.
1 Boiler, 12½ x 7½ ft.
1 Feed water heat.
1 Injector.
1 Small engine for boiler feed.
1 Small pump for washout.
1 Pump, 10 x 7 x 10 in., for hydraulic lift.
1 Each anvil, forge, bench, vise and pipe clamp, small blower and blower estimate.
1 Dynamo and small engine for lights.
1 Tank, 7 x 21 x 3 ft., for heating feed water for hydraulic lift in winter.
1 Cutter and 1 powder boat.

The cost of the plant was approximately $45,000.

On the Hay Lake and Neebish Channels improvement of St. Mary's River, Mich., Section No. 4, the following plant was used:

3 Drill boats, approximate value	$ 34,000
2 Dredges, approximate value	45,000
4 Dump scows, approximate value	30,000
1 Floating derrick, approximate value	6,000
2 Tugs, approximate value	10,000
Total	$125,000

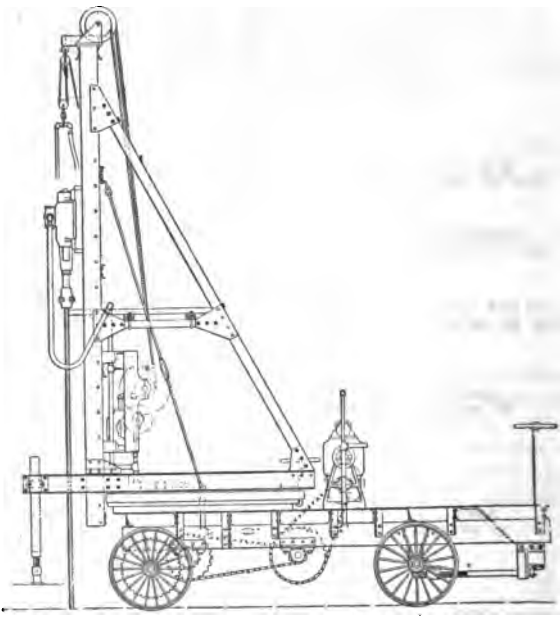


Fig. 150. 15 Ft. Feed Turntable Drill Wagon.

The drill boats have wooden hulls, 98 x 25 x 6 ft., 90 x 30 x 6 ft. and 65 x 16 x 5½ ft., the two largest having 3 drills each and the smaller 2 drills.

The tabulation on page 343 of the cost of subaqueous drilling is also abstracted from "Rock Drilling":

Deep Hole Drill Wagons. This type of drilling rig is adapted to work in the excavation of rock in quarries, canals, railroad cuts, and work of a similar nature, where the material to be drilled is too hard to use the ordinary rigs. They may be operated by a crew of two men, and are illustrated by Fig. 150. The following types are to be had: Portable wagon mounting for single drill, mounting for three or more drills; turntable drill wagon, and portable wagon mounting "electric air" drill, with or without turntable.

MISCELLANEOUS DRILLS

Channelers. These machines are used generally where the output of quarries consists of dimension stone, but sometimes, as on canal work, it is more economical to channel rocks to a required face than to drill and blast beyond the "pay" limit. Another definite advantage in the use of channelers is noted in the building of the Chicago Drainage Canal, where the walls were required to be left smooth and solid. The depth to which a channeler can cut depends upon the character of the rock. A cut as great as 17 ft. has been accomplished, but very rarely. The general average is from 7 to 10 ft. With a 9 ft. cut in shale, a machine under my direction, in February, 1908, cut from 80 to 250 sq. ft. per day of three shifts with a total of 3,139 sq. ft. for the month. The width of a channel cut will vary with the conditions from 1½ in. to 5 in., more or less. The cost per square foot channeled was 13.5 cents labor and about 4 cents for coal. These costs are exclusive of plant, superintendence and overhead charges.

In the fixed-back channeler the movement of the steels is limited to two vertical planes and the cut is vertical with square ends. The swing-back track channeler is intended for angular cutting in quarries where the floor is to be enlarged. And it is desirable to follow it without removing overlying rock. The Broncho channeler has a purpose intermediate between the heavy track channeler and the light quarry bar and drill. The under-cutting track channeler is designed to meet conditions in rock in which there are no free horizontal beds, and the cleavage of the stone is nearly vertical.

A steam operated double acting channeler with boiler, complete, weighs about 25,000 lb. and costs about $11,000. A similar

machine single acting, weighs about 16,000 lb. and costs about $7,000.

Gadder. The Gadder is used to drill a number of parallel holes in a plane, at any angle from horizontal to vertical, or, in connection with the channeler, in drilling the horizontal undercutting holes. In "plug and feather" work it is used to break the large blocks cut free by the channelers.

The equipment includes the following: Drill and standard

Fig. 151. Sullivan Steel Gadder.

mounted on carriage, with steady pins and adjusting screws, crank handle, oil cans, wrenches, etc., and does not include hose. Its weight complete, set up ready to run, is 4,100 lb. and it costs, about $1,400.

Quarry Bar. Complete quarry bars including carriage, weights and wrenches are made for drills having cylinder diameters of from 2 to 5 in. in lengths of from 8 to 12 ft. The shipping weights for the complete outfits are from 1,000 to 2,200 lb., and their cost is from $400 to $650 f. o. b. factory.

Electric Air Channeler. This machine is operated on the same principle as the electric air drill heretofore described. It costs about $5,000 f. o. b. factory.

When requesting quotations on rock drilling machinery, the following information should be furnished the manufacturer:

In Quarrying.

1. Give the location of work, whether on surface or underground.
2. Describe the nature of the rock, whether sandstone, slate, limestone, granite, marble, etc. State whether the material is hard, medium or soft.
3. Is the quarry output in dimension stone or simply broken rock?
4. If the material is shelly, state whether it is tight or loose.
5. What is to be the extreme depth of holes? Are there many or few of these deep holes?
6. What is the average depth of the holes to be drilled? (This is important.)
7. What is to be the average diameter of the holes at the bottom? If undecided, state whether dynamite or black powder is to be used.
8. What is the greatest distance to which steam will have to be piped or will ever be used?
9. A rough sketch of the quarry is very useful and also a small sample of the material to be quarried. If the latter is sent, it should be properly labeled with the name and address of the sender and prepaid; a 3-inch or 5-inch cube is a good size.

In Railway Cut or Excavation.

10. Give the full dimensions of the cut and in addition answer such questions in above list as may apply to the case.

In Sewer or Trenching Work.

11. Give answers to questions Nos. 2, 4, 6, 7, 8 and 9 above.
12. Give the width and depth of the trench, stating the depth of the rock which is to be removed, and depth of earth (if any) over the rock.

In Metal Mining.

13. Give full information as to the nature and quality of the ore.
14. Describe the general system of mining.
15. Give the dimensions of the shafts, drifts, stopes and winzes which are to be driven.
16. If a compressed air equipment is desired, answer the questions under the heading of "Compressed Air."

In Tunneling.

17. What is the nature of the material which is to be passed through?

18. Dimensions of tunnel?

19. What is to be the total length?

20. Are heading and bench to be driven together, or will a heading be driven first and the bench removed afterward?

21. Is the tunnel to be driven from one end only, or from both?

22. Are intermediate shafts to be sunk? If so, give their depth and cross-section, and describe the material to be penetrated.

23. If compressed air is to be used, distributed by pipes leading from a central station, these stations should be located where coal and water are most readily accessible. In such cases answer the questions under the heading "Compressed Air."

In Shaft Work.

24. What are to be the dimensions of the shaft?

25. Give the depth proposed and nature of the rock or ore penetrated. If compressed air is to be used, answer the questions under that head below.

In Submarine Drill Work.

26. Give the greatest depth of water over the rock to be excavated.

27. Give the depth of rock which is to be blasted and the depth of the holes to be drilled. If possible, state a maximum and minimum depth required.

28. Give the rise and fall of the tide, if any.

29. Give the velocity of the current, if any.

30. State whether the drilling is to be done from a scow, pontoon, platform or whatever support is used.

31. State whether the rock is covered with mud, clay, gravel or sand, and if so, to what depth.

Where Compressed Air Is to Be Used.

32. State the altitude above sea level at which the compressor is to be located.

33. Give a general idea of the location and arrangement of the plant.

34. State how near the plant is to fuel and water, and the kind and cost of the fuel.

35. State how far the compressing plant is from the work to be done.

36. If other machinery than drills is to be run by air, give the cylinder dimensions, the speed, the pressure necessary, the running time, the location, and other information likely to be of service.

37. State whether the compressor is to be run by steam, electricity or water power.

38. Give the steam pressure which is to be used.

39. State whether the compressor is to run condensing or non-

condensing. If condensing, state quality, temperature and quantity of water available.

40. If a boiler is already available, state its rated horse-power.

41. State how long the work is to last, and whether the most economical or a cheaper plant is contemplated.

42. If electric power is to be used, state character, voltage and frequency of current available.

43. If water power is to be used, state head and quantity available.

44. If the compressor must be sectionalized, state limit of weight permissible.

Pneumatic Piston Drills. Pneumatic piston drills are used for drilling metals, boring wood, tapping, reaming, flue rolling, etc. They are made in the reversible, non-reversible and close quarter types. They weigh from 10 to 75 lb. and are priced at from $75 to $195. Attachments may also be had for operating grinding wheels and saws.

Churn Drills. Churn drills or portable drilling machines are made in about fifteen sizes, some of the largest of which are also built with a traction attachment. The small portable and all the traction machines are usually equipped with a folding pole derrick, which takes up less space than a ladder derrick.

The prices of machines are about as follows:

TABLE OF CHURN DRILLS

Depth capacity in feet	Type	Approximate shipping weight	Price f. o. b. factory
250	Non-trac. fric. hoist steam	7,500	$1,540
500	Non-trac. cog hoist steam	9,500	1,815
500	Non-trac. cog hoist no power	6,800	1,180
500	Traction fric. hoist steam	12,000	2,270
400	Non-trac. cog hoist gas power	9,750	1,900
400	Traction cog hoist steam	13,000	2,360
800	Non-trac. cog hoist steam	10,000	2,000
800	Traction cog hoist steam	13,000	2,450
800	Traction cog hoist gas power	13,500	2,600
1000	Non-trac. cog hoist steam	14,000	2,260
1000	Traction cog hoist steam	16,000	2,720
2500	Cog hoist deep well rig	20,000	3,000
2500	Friction hoist deep well rig	22,000	3,550
3000	Friction hoist deep well rig	24,000	3,900
3500	Friction hoist deep well rig	28,000	4,350

The 400 ft. machine is adapted for blast hole drilling and may be had with either steam, gas engine or electric motor at approximately the price given above. This type of machine is illustrated by Fig. 152.

A rotary shot drill attachment including worm feed on rope reel, rotating table pulleys, and complete outfit that can be used with the 500 ft. machine in the above table, is used when it is

necessary to penetrate strata that cannot be drilled with the cable rig, costs $1150 f. o. b. factory.

Equipment for blast hole drilling adapted to the 250 and 500 ft. size is as follows:

2 4¼ in. fluted rock bits	$59.00
1 3¼ in. by 14 ft. stem	47.50
1 Set of thread protectors for pins	2.00
1 Set of thread protectors for boxes	1.00
1 Rope socket for 1¾ in. cable	19 80
2 Heavy tool wrenches for 2½ in. sq.	36.30
1 Chain wrench bar	8.25
1 Round bit gauge turned 4¼ in.	1.25
1 3 in. by 8 ft. sand pump	9.90
1 3 in. by 12 ft. sand pump	13.20
1 Blower steam driven	26.40
1 Tuyere iron	2.50
1 18 ft. blast hose	1.65
1 Rack and anvil billet for dressing bit	5.80
1 Smithing hammer	1.65
1 Sledge and handle	3.30
1 ¼ in. to 2 in. pipe wrench	4.40
1 Combination pipe and monkey wrench	5.00
1 Jar bumper	31.70
2 Lifting and lowering jacks	41.25
1 Piece 5⅝ in. casing 3 ft. long, clamp for starting	6.60
1 Conyone tool guide	41.25
200 ft. 1¾ in. manila H. L. drilling cable	
200 ft. ¾ in. manila H. L. sand line	

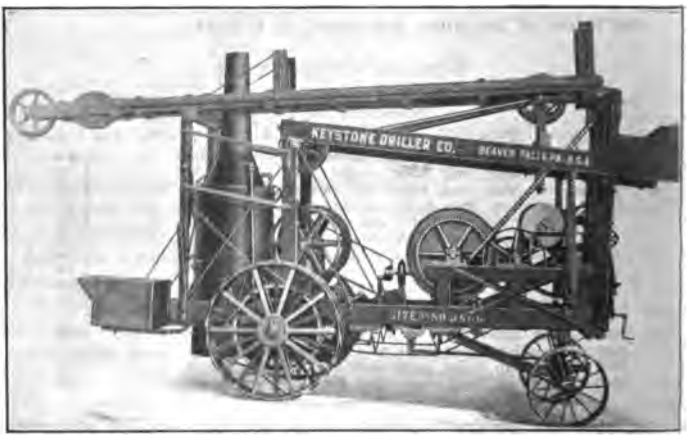


Fig. 152. Churn Drill.

Fishing Tools. Rope knife for cutting cable off close to rope socket, used on 1 in. gas pipe costs $14.00. Rope spear for fishing out a lost cable or sand line costs $10.50. Spuds for cutting around bit of tool that has become lost cost from $32 to $80

according to size. Sockets for fishing out tools cost from $35 to $100 according to size.

Mr. W. G. Weber, in the *Wisconsin Engineer*, described the use of churn drills in exploring low-grade copper ore bodies in Arizona. A drilling crew usually consisted of one driller and one helper or tool dresser, working in twelve-hour shifts. The costs of operation were as follows:

COST OF DRILLING

	Cost per Ft. of Hole	
Labor:		
2 drillers at $6 per day	$0.48	
2 helpers at $4.80 per day	.38	
1 sampler at $4 per day	.16	
1 foreman at $6 per day (2 machines)	.12	
		$1.14
Roads:		
Labor at $2 per day	$0.50	
Foreman at $4 per day	.05	
Powder, caps and fuse	.03	
Tools, etc.	.01	
		0.59
Coal, coke, oils, etc.		.27
Water		.10
Teaming		.10
Assaying, office and incidentals, etc.		.16
Interest at 5% and depreciation (life 4 yrs.) on $6,000 outfit		.20
Total cost per foot of hole (prior to 1912)		$2.56

The monthly average of the cost per foot of hole drilled varies with one company from $2 to $3. In another instance, where holes are drilled further apart and the drilling is poorer the cost per foot has run as high as $5. When drilling is the only means of development being used on a property, the cost of camp maintenance and incidentals considerably swells the cost account.

Mr. H. P. Gillette gives the cost of drilling blasting holes on the Pennsylvania railroad work. The drills used were the ordinary portable churn drills having engines of from 4 to 8 hp. driving a walking beam which raised and lowered a rope, to which was fastened the churn bit and rods. A 5⅝-inch bit was used in this work. Each drill averaged three 20-foot holes, or 60 feet, in shale per 10-hour shift. In limestone, however, and in hard sandstone, not more than 10 feet of hole were drilled per shift. Had the bits been reduced to 3 inches, and the drill rods suitably weighted, much better progress would have been made in hard rock.

Advantages of Churn Drills. Certain advantages of this type of drill over the regular rock drill are as follows:

(1) A drill will not so readily stick in the hole because of the

powerful direct pull of the rope that operates the drill rods; (2) there is no limit to the depth of the hole and the deeper it is (up to any limits possible in blasting) the better the drill works, due to the increased weight of the rods; (3) this type of drill consumes less fuel than the ordinary steam drill; (4) the weight of bits to be carried back and forth from blacksmith shop is much less than for the ordinary machine drills; (5) the driller will drill through the earth overlying the rock, so that no stripping is necessary; (6) the hole at bottom is much larger than with the ordinary drill, thus allowing the bulk of the powder charge to be concentrated at the bottom of the hole, where it should be. For the same reason a lower grade of explosive can be used.

Holes drilled with bits to give 3 inches diameter at the bottom of the hole, with depth of 24 feet in solid brown sandstone in Eastern Ohio. In 14 days of 10 hours each the driller put down 692 feet, or practically 50 feet per day.

Drill runner	$3.00
Drill helper and fireman	2.00
Pumping water	.60
6 bu. (480 lb.) coal at 10 ct.	.60
Total for 50 ft. of hole	$6.20

This gives a cost of 12½ cents per foot of hole, not including interest and depreciation, and bit sharpening. The best day's work in the brown sandstone, using all the weights, was 53 feet, but in blue sandstone, which was softer, 60 feet were drilled per day, using light weights.

In the same brown sandstone cut an 8-day test was made with a 3¼-inch Rand drill for comparison. The holes were 20 feet deep, 1¾ inches in diameter at the bottom (as against 3 inches with the well driller), and 28 holes were drilled in the 8 days, making 70 feet the average day's work. A 10 hp. boiler furnished steam. The daily cost of operating the Rand drill was:

Drill runner	$3.00
Drill helper	1.50
Fireman	2.00
Water	.75
10 bu. (800 lb.) coal at 10 ct.	1.00
Total for 70 ft. of hole	$8.25

This was equivalent to 11.8 cents per foot of hole, not including interest and depreciation, and bit sharpening, or slightly less than with the churn drill.

Mr. William R. Wade, in the *Mining World*, 1908, gives some costs of churn and core drilling in exploring for turquoise mines in the Burro Mountains, New Mexico. The machines used cost

$4,300, fully equipped and on the work. About 30 feet of 4-inch hole were cut in $8\frac{1}{2}$ hours at a cost of $1.00 per foot, including interest, repairs, superintendence and incidentals. Six barrels of water and $\frac{3}{8}$ cord of juniper (equal to pine, cedar or similar soft wood in fuel value) were used per day. Mr. Wade states that with a crew of three men the actual drilling cost about 50 cents per foot, including labor, interest on the drill, supplies and $1.00 per day for repairs, but not including office expenses, superintendence, assaying, etc.

Electric Driven Well Driller Used for Quarrying Crushed Stone as described in *Engineering and Contracting*, July 21, 1909, is equipped with a 10 hp. specially geared motor placed over the rear truck and belted to the drilling mechanism, which is back geared and balanced. The controller box is located at the front of the machine close to the driller's hand. The drilling tools comprise a stem weighing about 1,000 lb., a drill bit weighing 150 lb., and a rope socket weighing about 50 lb., or about 1,200 lb. altogether. The bit cuts a $5\frac{5}{8}$-in. hole and the stem is $3\frac{3}{4}$ in. in diameter and 22 ft. long. As the stroke is from 30 to 36 in., a blow of from 3,000 to 3,500 lb. is obtained at each stroke. The machine is built with gear hoist, capacity 500 ft., or with friction hoist, capacity 350 ft. The makers consider the latter style of machine probably the best for quarry and rock cut work where the tools are being constantly raised and lowered as in tamping a charge, and where the holes will rarely exceed 150 ft. in depth.

In operating at the full speed of the motor the tools make about 60 strokes per minute. As the hole becomes deeper or clogged with cuttings, before sand pumping, the rapidity of the stroke is gradually reduced to say 50 strokes per minute in order that the cutting bit may deliver its blow with best effect. This change of speed is produced by reducing the speed of the motor. The best results, it has been found, are obtained with a $5\frac{5}{8}$-in. hole. This size obviates the necessity of squibbing charges, which must be employed in smaller holes. A $5\frac{5}{8}$-in. hole is also more easily and cheaply drilled than a hole of larger or smaller diameter; the larger hole involves more cutting while permitting no corresponding gain in size and weight of drill bar; i. e., the heaviest practicable tools can be operated in a $5\frac{5}{8}$-in. hole, while a smaller hole necessitates a reduction in the diameter and weight of the stem and bit which cuts down their efficiency.

Besides doing the drilling this machine is used for loading the holes. For this service the regular drilling bit is removed and in its place a wooden rammer is placed on the drill stem. From 5 to 8 sticks of dynamite having been dropped into the hole the drilling tool is lowered after them, forcing them to the bottom

The tools are then withdrawn and the operation repeated until all the charge is placed. The placing of the firing cap and wires and the tamping are done by hand.

The machine was furnished by the makers on the guarantee to drill to a depth of 60 ft., at the rate of 40 ft. per 10-hour day, or 4 ft. per hour. In the tests made on delivery of the machine the following records were obtained: The machine was set up on June 5 at 5 o'clock and ran for 1 hour, drilling 9 ft. of hole. From the following Monday morning until Friday forenoon, something over 4 days, working 10 hours a day, four 66 ft. holes or 264 ft. of hole were drilled. In the following week four holes 105 ft. deep or 420 ft. of hole were drilled. These figures are furnished by the Keystone Quarry Drill Co. In actual work the machine averaged 40 ft. of 5⅝-in. hole per 10-hour day. The daily operating expenses are as follows:

One drill runner at $2.50	$2.50
One helper at $2	2.00
Cost of electric current	2.00
Oil, drill sharpening, etc.	1.50
Total per day (1909)	$8.00

This gives a cost per foot of hole drilled of 20 ct.

Ship Augers. A 3-in. ship auger, welded to a 6-ft. shank threaded to screw to a standard 1-in. water pipe, was used very satisfactorily by the Author in 1919 for making test borings in a clay pit to a depth of 30 ft. Where the clay is fairly dry this method is effective to a depth of 50 ft. The apparatus, shown in Fig. 153, consisted of a wooden tripod 12 ft. high when erected, a 1-ton chain-block, a rope tackle with one single and one double block, the 3-in. ship auger with welded shank and a couple of 12-ft. lengths of 1-in. standard water pipe. The cost of the outfit in October, 1919, was about as follows:

3 inch ship auger with welded shank	$ 25.00
Tripod made on the job from green timber by 3 men, 1 day, and 1 team ½ day	27.00
Rope tackle, 1 single, 1 double block	8.00
Chain block, 1 ton	60.00
2 Stillson wrenches for revolving the auger	5.00
Miscellaneous and overhead	25.00
Total (1919)	$150.00

The auger was found to be extremely well adapted to sinking a hole rapidly, taking out a core which gave a sample typical of the material at the bottom of the hole. The cost of the borings varied from about 25 cents per foot to one dollar, according to the condition of the material. Some holes were abandoned on account of striking rock or large boulders. Hard sand was an impediment, usually surmountable; and below a certain depth,

usually between 20 and 30 ft. the wet clay squeezed in the sides of the holes as soon as the bit was withdrawn, partly closing the hole, and thus making it impossible to go further with the next boring. This condition of plasticity of the clay thus defined the depth at which this method was practicable. After the bit was put down 8 in. or so into new material, it was pulled out for several feet with the block and tackle, using the chain block to start it where occasionally necessary, after which it was

Fig. 153. Ship Auger and Tripod for Test Borings in Clay.

lifted out by hand. Four men comprised the crew, which was directed by Mr. R. D. Sandford, of Litchfield, Conn.

Wash Boring. Wash boring is the most rapid and economical method of penetrating unconsolidated material. It is not a suitable means of prospecting where samples are required as all strata penetrated are mixed together and brought up by the water jet. It is particularly adapted to sounding the depth to rock when the overburden is too thick to be economically penetrated by augers. Where diamond drilling is to be done, wash boring is often used to penetrate the overburden.

Hand augers are used to bore through surface materials in starting a well. They are to be had in sizes of from 2 in. to 6 in. in various types. The price of the 3 in. size is $8.20.

Hydraulic, jetting and revolving drills used in rotary boring machines for enlarging a hole in order that a pipe casing may follow, may be had in a number of styles and are carried in stock in sizes from 2 to 16 in. A 3 in. drill costs $15.

Diamond Drilling. Diamond drills are used where it is necessary to obtain samples. The cores obtained may run from 10% to 100% depending on the condition of the material drilled. In cases where the rock is hard and uniform, core recovery is highest, and where the rock is loose and soft, recovery is low. Near the surface, where the rock is decomposed, recovery is less than at the lower portion of the hole.

A hand diamond drill outfit complete without diamonds, for 400 ft. depth, weighs approximately 2,200 lb. and costs $1,000. A gasoline driven outfit, same depth, without diamonds weighs approximately 4,000 lb. and costs $1,600. The same outfit driven by steam costs $3,500 and weighs approximately 11,000 lb.

For this type of drill six one and a half karat stones are used. The present price of a good quality stone is $115 per karat. The best practice is considered to have two sets of stones. The price would be $1,035 per set, or $2,070 for both sets.

The cost of diamond drill borings in the Colorado coal measures was given in *Engineering and Contracting*, Mar. 13, 1907 as follows:

The outfit used was a Sullivan Class CN coal prospecting drill, with a capacity of 500 ft., and 2-in. diameter core. This was complete with all necessary apparatus. Three sets of tubes were drilled, one of nine holes, one of seven holes and one of three holes. The drilling gang in each case was made up of one foreman at $150 per month, who had charge of the day drilling; one night driller at $3.50 per day; two assistants at $2.50 per day; one teamster at $2 per day, and a cook at $50 per month. The foreman kept records, set diamonds, bought supplies, etc. The men all received board and lodging.

The following figures are average costs per foot for each set of

	Set 1. Ct. per ft.	Set 2. Ct. per ft.	Set 3. Ct. per ft.
Foreman	7	6.8	18
Labor	115	81	170
Camp account	54	35	54.5
Supplies	8	2.3	12.8
Repairs	19	12.5	17
Carbon	86.6	22.1	65
Fuel	2	5	21
Total	$2.916	$1.647	$3.583

tubes. In Set 1 nine holes were drilled a total depth of 4,736 ft.; in Set 2 seven holes were drilled a total depth of 3,040 ft., and in Set 3 three holes were drilled a total depth of 1,767 ft.

The figures as will be seen do not include interest and depreciation on plant, transportation, etc.

Rotary Shot Drills. Rotary shot drills are used for the same purpose as diamond drills. In this type of drill steel shot are used to cut instead of diamonds. This machine is illustrated by Fig. 154. A machine driven by either steam (no boiler in-

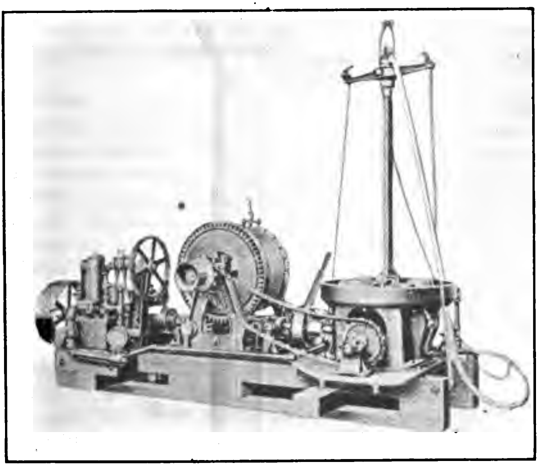


Fig. 154. Core Drill.

cluded), gasoline, horse or belt, capable of drilling to a depth of 300 ft. and recovering a 2½-in. core weighs from 2,600 to 4,000 lb. depending on the equipment, and costs from $900 to $1,300. Similar machines for depths of 800 ft. weigh from about 4,500 lb. to 7,000 lb. and cost from $1,900 to $2,000. The size of core in this machine is 3½ in. These machines are manufactured in sizes recovering cores to 19 in. in diameter and drill to any practical depth. They may be had with various power equipments.

The following cost data are from a report by Mr. F. R. Fisher on a drilling and grouting job at River Mill, Oregon. The total net cost of drilling and grouting was $47,770.55 or $1.40 per lineal foot. Of the total footage drilled 32,919 lineal feet were put

down by rotary shot drills and 1,119 feet with diamond drills. The holes put down with the diamond drills cost about one-third more than those with the shot drill.

Rock Sounding Rig. The following description of a rock sounding rig appeared in *Engineering News*, Apr. 8, 1915.

A simple rig which has been used both to obtain the thickness of earth cover over rock and as a drill for blast holes in soft shale or hardpan has been devised by J. L. Weller, Engineer in

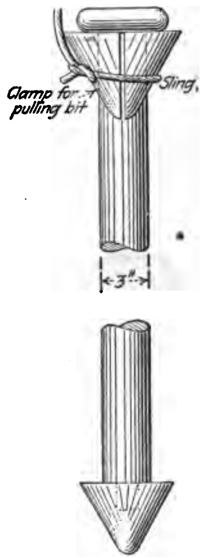


Fig. 155. Bar and Attachments for Rock Sounding Rig.

Charge of the Welland Canal, St. Catharines, Ont., and has been used on the revision work in that canal and on an earthwork contract in Nova Scotia.

The rig essentially is a light piledriver which is used to hammer a long bar into the ground. The piledriver is about 25 ft. high and weighs about 200 lb., so that it is easily portable by two or three men. It carries a 135-lb. hammer operated by hand through a single line over a sheave at the top of the leads. The bar is 3 in. in diameter, with an upset head and a tenon point into which fits a driving point of conical shape and slightly

larger outside diameter. New driving points, at a cost of 2c. apiece, are provided for each operation, the old one being left in the hole. For pulling the bar a clamp in the shape of a bifurcated cone is fitted under the head of the bar and the pile-driver rope slung around the clamp. A pull on the rope tends to bind the clamp to the bar and at the same time to pull the bar upward.

The rig was used extensively on the Welland Canal work to locate the rock surface, which lay in a fairly uniform plane beneath the ground surface. The easily portable rig made quite easy and cheap the determination of rock depths at close spacings. On the Nova Scotia job the rig worked ahead of the steamshovel, making blast-holes for small shots to break up the shaly formation.

Sand Pumps. "Down" holes in rock forming a mud which will not splash out must be cleaned at intervals — usually at every change of steels. For this purpose the sand pump is used. It is a section of wrought iron boiler tube having a valve at its lower end which opens to admit the slush, but closes when the tube is lifted. At the upper end of the tube a chain should be attached, made up of several links of rod by which the pump is forced to the bottom of the hole. A ring at the last link prevents the chain from dropping in the hole. The two-foot length is used for cleaning holes without moving the drills; greater lengths are intended for deep holes. Standard sizes and prices are tabulated below.

SAND PUMP WITH BAIL

8-ft. lengths

Outside dia. in in.	Price f. o. b. factory	Price per ft. extra length
1 13/16	$ 8.25	$0.75
2 13/16	9.90	0.75
3¾	16.50	1.50
4¼	19.80	1.50
4¾	21.40	1.50

Sand pump bottoms of cast iron cost $2.20 for the 1 13/16-in. size, $2.50 for the 2 13/16-in. size, $2.90 for the 3¾-in. size, $3.30 for the 4¼-in. size and $3.75 for the 4¾-in. size. For cast steel add 100% to price.

Blacksmith drills operated by hand power, for drilling holes up to 1½ in., weigh from 90 to 150 lb., and cost from $12.00 to $25.00.

SECTION 35

ELECTRIC MOTORS

Electric motors used by contractors in general construction work range in size from a fraction of a hp. to about 150 hp. Direct current motors may be furnished shunt, series or compound wound. Shunt wound motors maintain a perfectly constant speed regardless of load. They are used when constant speed is required under changed loading conditions and are particularly suitable for driving line shafting or groups of machines operated by one motor. Series wound motors vary in speed in proportion to the load carried. They exert a very strong start torque and will race if allowed to run free. They are particularly suitable for operating cranes, hoists, etc., where frequent reversals are necessary and where the speed of the motor is constantly under the control of an operator.

Compound wound motors combine the advantages of the shunt and of the series wound motors. They will vary in speed under changed loading conditions more than a shunt wound motor, but they will not race nor slow down under a heavy load to such an extent as a series wound motor. They are adapted to driving pumps, etc., where fairly steady speed and starting torque are required.

The single phase alternating-current motor has been quite well developed during the last few years, but it has as yet come into rather limited use. The polyphase motor has come into very general use, its relative simplicity being a strong feature. These induction motors may be either of two general types, the squirrel cage type and the slip ring, or wound motor type. The squirrel cage type is the more simple and has no moving contacts, and hence no wearing parts except the bearings. Relative freedom from sparking is assured and the motors can be used with some safety in locations surrounded by inflammable or explosive material. For constant speed service with fairly infrequent starting or with frequent startings on circuits where close voltage regulation is not essential the squirrel cage is the preferable type. The slip ring type, however, by the use of adjustable starting resistance in series with the secondary, will

start a given load with less current, and is therefore preferable where frequent starting with heavy load is necessary and where close voltage regulation is essential. The slip ring motor is also useful for some kinds of varying speed service, notably hoists and cranes, where its service is comparable to that of a series wound d. c. motor.

Motors for a variable speed use are designed for intermittent service of a maximum of 30 minutes duration and this reduces the cost. Motors when well protected have a long life. The brush is the quickest wearing part and one will last from 1 to 4 years, depending on the care given and the kind of service. When a motor is overloaded the brush sparks and, therefore, wears out very rapidly. A brush will last longer on alternating current than on direct.

The following table gives the average prices of direct current motors, also the weights. There is a variation in the cost of about 15% either way, and of the weights a variation of about 30% either way. These figures are useful in estimating and are for machines rated at 500 r.p.m. Machines rated at other speeds cost more for the slower types and less for the faster types per hp.

Size in hp.	Weight in lb.	Price f. o. b. factory
1	335	$ 125
3	700	195
5	1000	275
7½	1350	345
10	1680	405
15	2250	520
25	3250	700
50	5450	1050
75	7250	1360
100	8900	1630
150	12000	2140

The following is the average cost of alternating current motors 60 cycle for 110 to 220 volts two or three phase rated at 1200 r.p m. The same variations of weights and prices apply to these motors.

Size in hp.	Weight in lb.	Price f. o. b. factory
1	155	$ 60
5	360	125
10	620	206
15	875	270
20	1150	350
25	1400	390
50	2500	650

D. C. Motors. The following table gives the prices of one make of motors and applies to motors operating on 115,230 and 500 volts. The prices are for complete machines with base, pulley and starter.

hp.	Speed r. p. m.	Approximate shipping weight	Price f. o. b. factory
1	850–1925	165–235	$ 77–102
3	1150–1750	385–400	140–185
5	850–1750	400–750	185–295
10	760–2000	750–1310	300–435
15	1150–1900	940–1310	345–425
20	715–1750	1420–1750	415–730
25	600–1750	1420–2360	550–900
30	600–1750	1660–2940	650–1050
45	800–1050	2350–2940	850–1050
55	500–1100	2800–5050	1000–1800
70	600–825	3200–5050	1350–1840
100	375–615	5400–6100	2200–2830
165	425–510	7000–9900	3190–4000
190	475	9400–9900	3680–4050

D. C. Generators. The following gives the cost of a make of generators. These machines are rated at voltages of 125 and 250 and the prices include sliding base, pulley and field rheostat.

K. W.	Speed r. p. m.	Approximate shipping weight	Price f. o. b. factory
1	1050	225	$ 102
2	1200	410	180
3	1150	620	250
5	1000	725	368
10	950	1175	490
20	600	2250	1000
25	580	2750	1130
50	900	3175	1400

A. C. Motors, squirrel cage, are made for voltages of 110, 220, 440 and 550 for 2 or 3 phase 25 and 60 cycles (most common). The following table gives the prices of these motors for 60 cycles. The prices given are for motors rated at 1,200 and 1,800 r.p.m. no load speed. These motors may be had in no load speeds of 600, 720, 900, 1,200 and 1,800 r.p.m. The speed at full load is from 30 to 50 r.p.m. less.

hp.	Approximate shipping weight in lb.	Price f. o. b. factory
1	110	$ 75
3	245	100
5	300	130
10	430	280

A. C. Motors, slip ring, are made in the same voltages as the squirrel type. The following are for motors rated at 1,200 r.p.m. for 2 or 3 phase, 60 cycle.

hp.	Approximate shipping weight in lb.	Price f. o. b. factory
1	280	$ 210
3	395	294
5	455	341
10	590	445
20	915	613
30	1175	767
50	1655	946
75	2195	1333

The prices for these a. c. motors are for the complete motor on base with pulley and starter.

In general the prices are less for the higher speed motors and more for the slower speed.

SECTION 36

ELEVATING GRADERS

These machines are generally drawn by twelve horses (eight in front and four hitched to a push cart behind) or more, or by a traction engine. The machine consists primarily of a plow which casts a furrow on a transversely moving belt that elevates the earth, and dumps it into wagons or at one side.

An all steel elevating grader equipped with an 18 ft. elevator which can be shortened to 15 ft. by removing one section weighs approximately 7,080 lb. for shipment and costs $1,250 f. o. b. factory. A larger sized machine weighing 7,650 lb. costs $1,450 f. o. b. factory. The manufacturers claim that these machines are capable of throwing 1,000 yd. of earth into embankments, or loading from 5 to 600 1½-yd. wagons in 10 hr. work where the condition of the soil is suitable for their operation.

The following is the cost of stripping a gravel pit, covered with sandy loam, with a number of pockets of varying depths up to 10 in. The contract called for the stripping of a space 3,000 feet long and 250 feet wide, and the placing of the material in storage piles in the rear.

The outfit consisted of 1 elevating grader 6 1¼-yd. dump wagons, 4 No. 2 wheelers, and 2 plows. Wheelers were used to excavate the pockets. More wagons should have been provided as the grader was delayed waiting for them.

19,970 cubic yards were stripped during the month of September, 1909.

Grader —	
2½ Teams on push, 24 days, @ $5.00	$ 300.00
8 Teams on machine, 24 days, @ $5.00	960.00
Wagons —	
5½ Teams, 24 days, @ $5.00	660.00
Wheelers —	
3 Teams on wheelers, 11 days, @ $5.00	165.00
1 Team on plow, 11 days, @ $5.00	55.00
1 Team on scraper, 11 days, @ $5.00	55.00
Labor —	
1 Foreman	85.00
1 Mucker, 24 days, @ $2.00	48.00
1 Corral man, 28 days, @ $2.00	56.00
2 Grader drivers, 24 days, @ $2.25	108.00
Total cost at 12½ cents per yard	$2,492.00

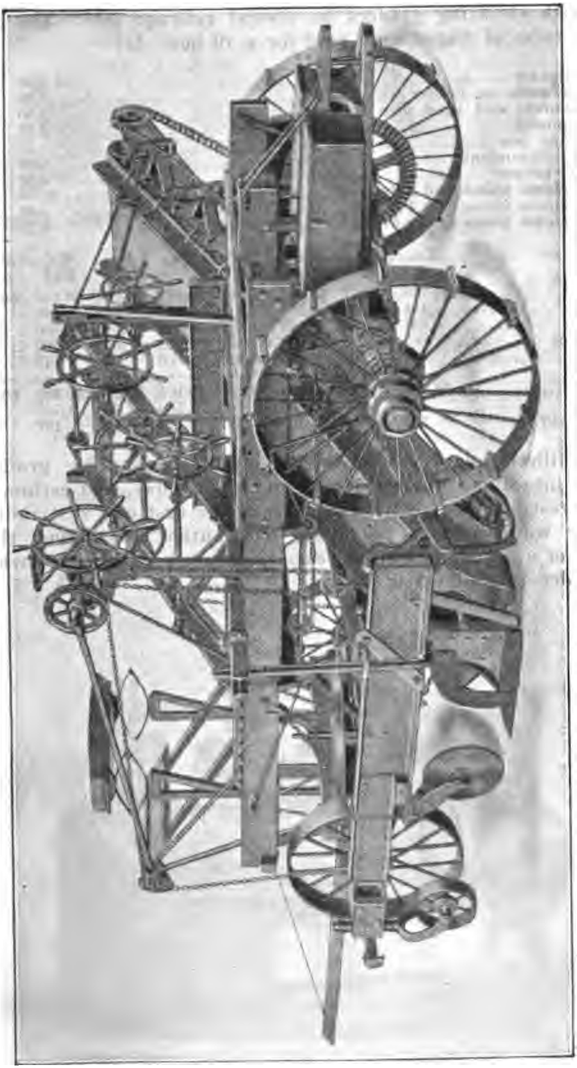


Fig. 156. Elevating Grader and Wagon Loader.

Mr. Daniel J. Hauer gives the cost per cu. yd. of earth excavation with elevating graders on several railroad jobs. The following rates of wages were paid for a 10 hour day:

Foreman	$ 2.50
Operators on grader	1.50
Laborers and team men	1.50
Engineer	2.75
Water boy	.75
Superintendent	3.00
Timekeeper	2.50
12 Horse teams and 2 drivers	22.60
2 Horse teams and 1 driver	4.60
3 Horse teams and 1 driver	6.25

	Ex. I.	Ex. II.	Ex. III.	Ex. IV.	Ex. V.	Ex. VI.	Ex. VII.	Average.
Loading	$0.130	$0.067	$0.085	$0.108	$0.061	$0.098	$0.153	$0.100
Hauling	.111	.078	.117	.149	.077	.094	.260	.127
Dumping	.041	.011	.019	.019	.018	.049	.050	.029
Water boy	.001	.002	.002	.003	.002	.003	.002	.002
Foreman	.012	.007	.015	.010	.006	.009	.015	.010
Total	$0.295	$0.165	$0.238	$0.289	$0.164	$0.253	$0.480	$0.268
Lead, ft.	400	1,000	600	700	500	500	1,700	800
Cu. yd. per day	206	380	300	284	417	260	167	288

Mr. Gillette places the average output of elevating graders loading into dump wagons at 500 cu. yd. per day, and estimates the interest and depreciation as 20% of the first cost distributed over 60 working days per year. The author has found that the life of a grader is from 5 years to as much as 12 years when the grader is well cared for.

SECTION 37

ENGINES

Simple, Center Crank Engines without boilers cost as follows:

hp.	r. p. m.	Weight	Price
4	225	750	$232
5	215	825	254
6	200	1270	282
8	200	1300	306
10	190	1950	346
12	180	2025	368

The prices of the same engines mounted on locomotive boilers, which in turn, are mounted on either wheels or sills, are as follows:

ON WHEELS

hp.	Weight in lb.	Price, f. o. b. factory
4	3,700	$ 850
5	4,050	925
6	4,400	1,060
8	4,900	1,125
10	6,050	1,250
12	7,350	1,410

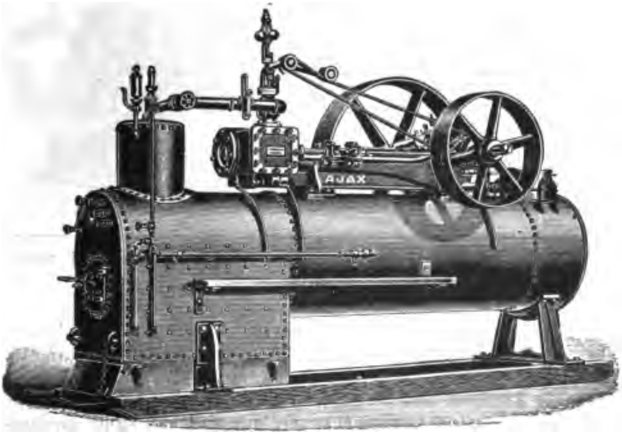


Fig. 157. Center Crank Engine on Skids.

On Sills

4	2,580	$ 760
5	3,030	805
6	3,380	905
8	3,700	970
10	4,740	1,075
12	5,950	1,210

A single cylinder, center crank, horizontal steam engine similar to the one in Fig. 157, complete with sub-base and all fittings, costs as follows:

hp.	r.p.m.	Weight	Price
15	280	2000	$585
20	280	2050	605
25	260	3000	725
30	260	3050	750
40	220	4800	925
50	220	4900	955

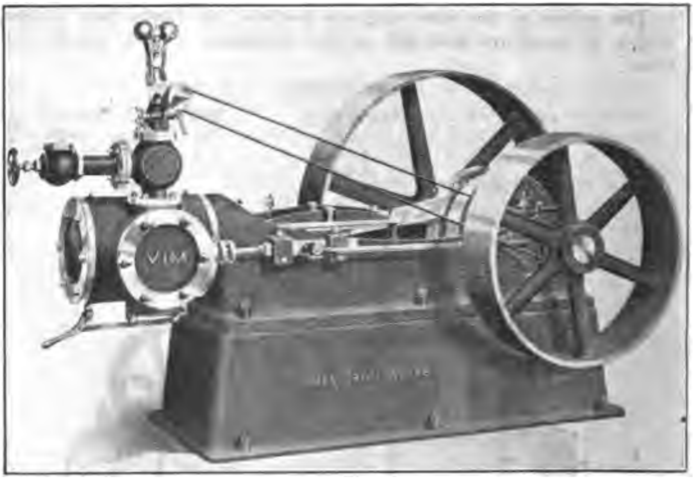


Fig. 158. Single Cylinder, Center Crank Horizontal Steam Engine.

The above ratings are based on a steam pressure of about 80 lb. at the throttle.

Portable Engines and Boilers on skids similar to the one shown in Fig. 158 have locomotive type boilers and the same engines as above.

hp.	Weight	Price
10	6000	$1,300
20	6850	1,600
30	8500	1,945
40	9050	2,450
50	11400	2,800

Above prices f. o. b. New York.

Another make of portable engine costs as follows f. o. b. Racine, Wisconsin:

Rated hp.	Steam pressure	Price
18	140	$ 800
50	150	2,200
65	150	2,300
80	150	2,400

These engines are complete with locomotive type boilers and side or disc crank engines. They are mounted on large wheels with wide tires.

Estimating the Horse Power of Contractors' Engines. The size of an engine is usually expressed in terms of the diameter of the cylinder bore by the length of the piston stroke. In a 6 x 8 engine, the cylinder has a bore of 6 in. and the piston has a stroke of 8 in. This stroke is, of course, just twice the length of the "throw" of the crank arm. Bear in mind, therefore, that the "size of cylinder" as given in catalogue is the bore of the cylinder by the stroke of the piston, and not by the full length of the cylinder.

If a contractor's engine is designed to have a piston speed of 300 ft. per minute, and is using steam with a boiler pressure of 100 lb., it is an easy matter to deduce a very simple rule for estimating the horse-power of the engine. The following rule is precisely correct when the product of the piston speed by the mechanical efficiency is equal to 1,050; and this is ordinarily the case with contractors' engines having cylinders of 8 in. or more in diameter.

RULE: To ascertain the horsepower, square the bore of the cylinder and divide by four.

Thus, if the engine is 8 x 8, we have a cylinder bore of 8. Hence, squaring 8 we have 64, and dividing by 4 we get 16, which is the horsepower. This is the actual delivered, or brake, horsepower. For small engines, whose piston speeds are usually less, it is safe to divide the square of the bore by five instead of by four. A 6 x 6 engine would, therefore, have 7 horsepower.

If the engine has two cylinders (duplex) of course the horsepower is twice that of a single cylinder.

Gasoline Engines are usually furnished with the machinery they are designed to operate, and for that reason when machinery

which may be operated by gasoline is described, the price of the engine is included in the total cost. However, at times, it may be desirable to equip a piece of machinery now driven by steam or other power, with a gasoline engine.

A gas, gasoline or kerosene driven engine of a horizontal water cooled type is of four cycle, with built in magneto, centrifugal governor, and has the fuel supply tank in the base of the engine. The price of the engine on iron sub-base is as follows:

hp.	Approximate shipping weight in lb.	Price f. o. b. factory
1½	350	$ 85
3	550	125
5	950	195
8	1950	425
12	2400	510

This price includes complete equipment.

The same type engine mounted on an all steel truck is as follows:

hp.	Approximate shipping weight in lb.	Price f. o. b factory
1½	450	$125
3	650	185
5	1050	275
8	4000	660
12	5000	800

In the above table the 1½, 2, 3 and 5 hp. sizes are mounted on hand trucks; the 8 and 12 hp. sizes are mounted on trucks with pole and may be had with single or double trees at an additional cost.

Care of Gasoline Engines in Freezing Weather by Use of Anti-Freezing Mixtures. The following are rules for avoiding freezing of water in the cylinders, pipes, radiators, etc., of the cooling system of water-cooled automobile engines and stationary explosive engines. As soon as freezing weather approaches or when the temperature drops as low as 40 degrees F. all water should be drained from the radiator, cylinders and pump, says *Gas Review*, and the radiator filled with one of the solutions given.

1. A mixture of glycerine and water in the proportion, by weight of 25% of the former and 70% of the latter, to which is added 2% of sodium carbonate.

2. Chemically pure calcium chloride dissolved in hot water in the proportion of 4 pounds to one gallon of water.

3. Sodium chloride (common salt) or magnesium chloride dissolved in water in the proportion of 1½ to 2 pounds to the gallon.

4. Wood alcohol in the proportion of 20% alcohol to 80% of water. This solution has the advantage of being sufficient for average winter weather, and it has no ill effect of any kind on metals nor does it leave any sediment.

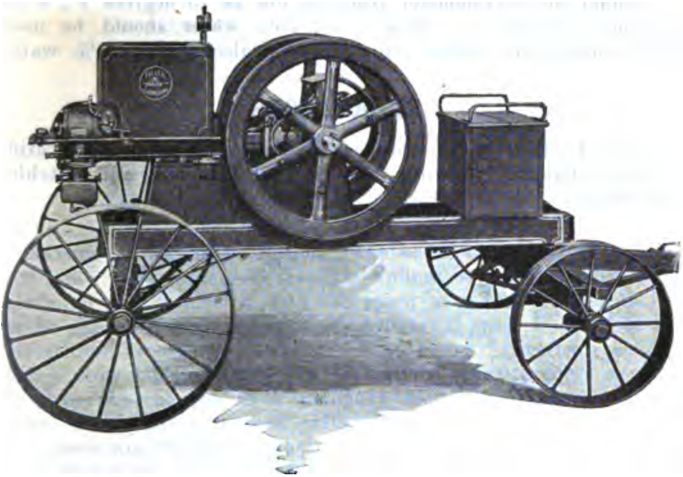


Fig. 159. Gasoline Engine on Trucks.

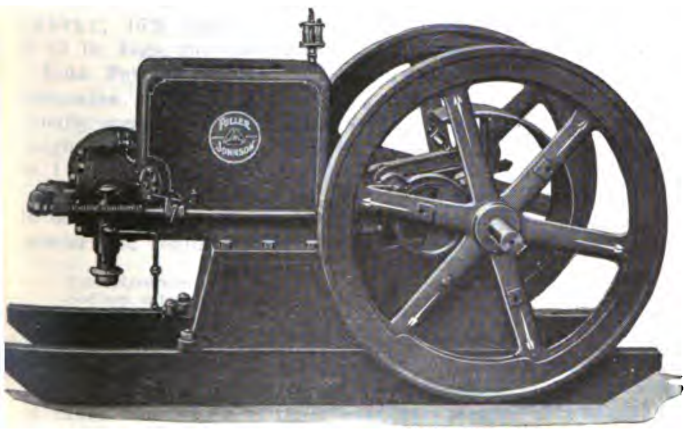


Fig. 160. Gasoline Engine on Skids.

Should the thermometer reach as low as 15 degrees F., a solution of about 25% alcohol and 75% water should be used. For temperatures below zero, use 30% alcohol and 70% water.

EXCAVATORS

(See Buckets, Drag Scraper Excavators, Dredges, Elevating Graders, Grading Machines, Shovels, and Trenching and Ditching Machines.)

SECTION 38

EXPLOSIVES

Nature of Explosive Action. The value of explosives in construction work is derived from the volume of gas generated upon detonation or explosion, and the speed at which the generation takes place. The pressure of the generated gases is equal in all directions (contrary to the belief of many "practical men"), but a slow burning black powder will take many times as long to generate the gas as a detonant like nitroglycerine. Dynamite will shatter a rock without even a mud cap, because the gases are liberated with such extreme velocity that the effect is produced on the rock before the atmospheric air can overcome its own inertia and yield.

Gunpowder. There are the following general classes of black powder manufactured:

Nitre Powder, the highest grade, consists of 75% saltpetre (KNO_3), 15% charcoal, and 10% sulphur. It usually comes in 25 lb. kegs, and costs about $9.25 per keg.

Soda Powder contains sodium nitrate ($Na\ NO_3$), which deteriorates in time by absorbing moisture from the air. It usually comes in 25 lb. kegs and costs about $2.25. The average weight of loose powder, slightly shaken, is 62½ lb. per cu. ft., or 1 lb. occupies 28 cu. in.

Judson Powder, which is a free running black powder, comes in 50 lb. kegs and costs about $7.25 and under. It is a soda powder and contains from 5 to 10% of nitroglycerine.

Nitroglycerine	5%
Sodium nitrate	64%
Sulphur	16%
Cannel coal	15%

Dynamite consists of any absorbent or porous material saturated or partly saturated with nitroglycerine. The absorbent is called the "dope." If 40% of the weight of dynamite is nitroglycerine it is known as 40% dynamite; if 75%, it is known as 75% dynamite.

High explosives are usually packed in cases containing 25 and 50 lb. "Car load" means 20,000 pounds dynamite net weight,

except where the railroad requires a larger minimum quantity, in which event that minimum quantity is considered a car load. Prices on 200 pounds or more usually include delivery to the nearest freight station. The prices of high explosives vary in the different sections of the country as much as $2.00 or $3.00 per one hundred pounds. For instance, in greater New York and most points in Colorado and Florida they are high; in Maryland, Pennsylvania and the greater part of New Jersey they are low as a rule. The price in any section is liable to change without notice and their variation is due to many different causes, such as high or low freight rates, local ordinances regarding the method of delivery, etc., hence, the rates given below are average and are mainly of use in determining the relative prices of different kinds and grades of explosives.

Average Prices of High Explosives

Strengths	Price per 100 lb.	
%	Ton lots	Less than ton lots
20	$17.25	$18.50
25	19.65	20.90
30	20.00	21.00
35	20.90	22.15
40	21.00	22.50
50	22.50	23.50
60	23.50	24.75
75	27.00	28.25
80	28.25	29.50
90	30.75	32.00

Permissible Explosives

Kind	Price per 100 lb. Ton lots	Less than ton lots
Monobels 1 & 6	$22.00	$23.25
Monobels 2, 3, 4 & 5	20.50	21.75
Carbonites 1 & 2	19.00	20.25
Carbonites 3 & 6	17.00	18.25

Red Cross Explosives are especially valuable in cold weather because although they will freeze, they do not freeze readily and will thaw when ice melts. Identical in appearance and similar in action to other standard grades.

Ammonia Dynamite has a strong heaving and rending effect, producing a minimum of fine material. Fumes not objectionable. Difficult to ignite by "side spitting" of fuse. Suitable for open or underground work.

Semi-Gelatin is an excellent explosive for wet work. No objectionable fumes.

Gelatin Dynamite is dense, plastic, fumes not objectionable. Little affected by water.

Blasting Gelatin is a very high power, quick-acting explosive

Table of Outside Dimensions and Shipping Weights of Cases.

Explosive	Case No. 1 Capacity 50 lb. Net Wt. lb.	Case No. 1 Dimensions L. W. D.	Case No. 2 Capacity 50 lb. Net, in Cartons Wt. lb.	Case No. 2 Dimensions L. W. D.	Case No. 3 Capacity 25 lb. Net Wt. lb.	Case No. 3 Dimensions L. W. D.	Case No. 4 Capacity 25 lb. Net, in Cartons Wt. lb.	Case No. 4 Dimensions L. W. D.
Nitroglycerin dynamite	58	17½x12 x 9	60	25½x 9¾x9	29½	13½x9½x8		
Extra dynamite	58	17½x12 x 9	60	25½x 9¾x9	29½	13½x9½x8		
Gelatin dynamite	58	17½x12 x 8	60	25½x 9¾x9	29½	13½x9½x8		
Blasting gelatin	58	17½x12 x 8			29½	13½x9½x8		
Judson R.R.P. (bags)	59	17½x12 x11¼			29½	13½x9½x8		
Judson powder	58	17½x12 x 9						
Monobel No. 1			65	18½x16¾x9¾			34	16¾x10 x9¾
Monobel No. 2			65	18½x16¾x9¾			34	16¾x10 x9¾
Monobel No. 3			65	18½x16¾x9¾			34	16¾x10 x9¾
Monobel No. 4			65	18½x16¼x9¾			34	16¾x10 x9¾
Monobel No. 5			65	18½x16¾x9¾			34	16¾x10 x9¾
Carbonite No. 1	58	17½x12 x 9	65	25½x 9¾x9½	29½	13½x9½x8	32	14 x 9¾x8½
Carbonite No. 2	60	17½x13½x11¼	65	18½x16¾x9¾	31	19 x9½x8	34	16¾x10 x9¾
Carbonite No. 3	60	17½x13½x11¼	65	18½x16¾x9¾	31	19 x9½x8	34	16¾x10 x9¾
Carbonite No. 4	58.5	17½x13 x 9			31	14 x9¾x8½	32	14 x 9¾x8½
Carbonite No. 5	60	17¼x13½x11¼	65	18½x16¾x9¾	31	19 x9½x8	34	16¾x10 x9¾
Carbonite No. 6	60	17½x13½x11¼	65	18½x16¾x9¾	31	19 x9½x8	34	16¾x10 x9¾

with good water resisting qualities and a lack of objectionable fumes. For use in rock too hard for 80% Gelatin Dynamite.

A "permissible explosive" is one which has been approved by the United States Government as "permissible for use in gaseous or dusty coal mines."

Monobel No. 2 and Carbonite No. 1, are recommended for anthracite coal, bituminous coking coal and other coal where a quick acting explosive is needed.

Monobel No. 3 and Carbonite No. 4 are slower in action, and should be used where a maximum of large lump is desired.

Carbonite No. 2 is slower than No. 1 and quicker than No. 3.

Monobel No. 1 is designed for use in quarries and ore mines. It does not require thawing, and is practically fumeless.

Judson powder is intermediate between dynamite and blasting powder. It is especially valuable in soft and friable work. Judson R. R. P. has already been described.

Judson F, FF and FFF are put up in cartridges like dynamite.

The weight of dynamite per inch of stick is about as follows, and all of the grades weigh about the same per stick:

Dia. of stick (in.)	Wt. per in. of length (lb.)
1	0.042
1¼	0.065
1½	0.094
1¾	0.128
2	0.168
2¼	0.212

EXPLOSIVES STORE HOUSES

Professor Courtenay de Kalb, in his "Manual of Explosives," says:

"Storage (of explosives) in caves, tunnels, earth or stone covered vaults and in log structures should under no circumstances be tolerated. The chief objection in all theses cases is that the structure will hold dampness, and any dampness in a magazine containing any explosive into which nitrates enter as an essential or accessory ingredient is certain to affect its quality and render it more or less dangerous in subsequent use. This applies to gunpowder (common black powder) and to practically all dynamites . . ."

Professor de Kalb recommends a building of tongued and grooved boards, blind nailed, with tar-paper covered roof, and if danger of fire is apprehended, steel shingled covered roof and walls. An ordinary tool box covered with tin or sheet iron and painted red with large, distinct "danger" signs on all sides

is excellent. However, it is possible to obtain ready made magazines.

On October 1, 1911, Massachusetts, New Jersey, Ohio, California, and Oklahoma had laws regulating distances at which specific quantities of explosives might be stored with reference to dwellings, public buildings, railroads, etc. Almost all cities and towns have laws regarding this and all who intend to store explosives should inform themselves on all state and local laws. Where no laws affecting storage of explosives are in force, we recommend that magazines be located in compliance with the American Table of Distances, to-wit:

Pounds of explosives	Distances to inhabited buildings when magazine is barricaded (ft.)	Distances to unprotected inhabited buildings (ft.)	Distances to passenger Ry's. when magazine is barricaded (ft.)	Distances to unprotected passenger railways (ft.)
100	180	360	110	220
200	260	520	155	310
300	320	640	190	380
400	360	720	215	430
500	400	800	240	480
600	430	860	260	520
700	460	920	275	550
800	490	980	295	590
900	510	1,020	305	610
1,000	530	1,060	320	640
1,500	600	1,200	360	720
2,000	650	1,300	390	780
3,000	710	1,420	425	850
4,000	750	1,500	450	900
5,000	780	1,560	470	940

Where municipal regulations do not prohibit storing explosives within city limits, powder or dynamite in quantities of 100 pounds or less may be kept in a small portable magazine. Always mark on this magazine the words "Powder Magazine." Fuse may be kept in store and blasting caps or electric fuses, not exceeding 500 each. Always keep magazine locked.

Sidewalk Magazine Without Wheels. A magazine built of 2-in. boards covered entirely on the outside with No. 20 flat iron, having the lid secured by ordinary hinges and fitted with hasp, staple and padlock. (No magazine should be allowed to rest on the ground because powder absorbs moisture.)

COST

For 50 lb. powder, 22″ wide x 27″ long x 17″ high	$10 to $20
For 100 lb. powder, 27″ wide x 27″ long x 22″ high	12 to 24
For 50 lb. dynamite, 19″ wide x 28″ long x 13″ high	12 to 24
For 100 lb. dynamite, 19″ wide x 28″ long x 22″ high	14 to 28
For 200 lb. dynamite, 25″ wide x 36″ long x 22″ high	18 to 36
For 300 lb. dynamite, 25″ wide x 50″ long x 22″ high	22 to 44

Sidewalk Magazine with Wheels. Similar to that without wheels, but supplied with four 6-in. cast iron wheels on the outside at the bottom.

COST

(Has same dimensions as those without wheels)

For 50 lb. powder	$12 to $24
For 100 lb. powder	14 to 28
For 50 lb. dynamite	14 to 28
For 100 lb. dynamite	16 to 32
For 200 lb. dynamite	20 to 40
For 300 lb. dynamite	24 to 48

Iron Magazines for storing explosives are of two kinds; the portable sidewalk magazine on wheels, and the storage magazine. The former is furnished in five sizes from that with a capacity of eight kegs, size 24 x 23 x 35 in., weight 150 pounds, price $35 f. o. b. Ohio, to that with a capacity of thirty kegs, size 30 x 30 x 50 in., weight 450 pounds, price $85. The latter kind comes in ten sizes, from the smallest, capacity 108 kegs, size 3 x 6 x 6 ft., weight 800 pounds, price $115, to the largest, capacity 1,848 kegs, size 11 x 8 x 21 ft., weight 4,700 pounds, price $675.

General Specifications for Sand Filled Dynamite Magazine are as follows:

Foundations:

If a post foundation is used, posts spaced 5 ft. c. to c. and charred or tarred.

If brick foundation is used, 9-inch wall stepped to 12 or 15-inch footing course, all laid with lime or cement mortar.

If stone foundation is used, wall may be laid dry.

If concrete foundation is used, wall need not be more than 8 inches thick.

Floor:

Joists: 2 in. x 6 in., spaced 12 in. c. to c.

Floor: ⅞-in. matched boards, blind nailed, or 1-in. board with nails countersunk.

Sills and Plates:

2 x 6 in.

Studding:

2 x 6 in.

Siding:

⅞-in. tongue and groove, or shiplap.

Lining:

Sheath inside of building from sills to plate with ⅞-in. tongue and groove blind nailed, or shiplap with nails countersunk.

Bullet Proofing:

As inside sheathing is put on fill space between the sill, plate, studding, outside and inside sheathing with coarse sand, well tamped. Do not use gravel or stone.

Roof:

Rafters: 2 x 4 in., spaced 24 in. c. to c. Sheathing, 1-in. plank.

Roofing:

No. 24 galv. corrugated iron.

Cornice:

(Under eaves) No. 26 galv. flat iron. To make roof bullet-proof from above, nail plank on rafters and fill with sand.

Iron Covering:

Sides and ends to be covered with No. 24 or No. 26 black or galv. flat or corrugated iron.

Door:

3-in. hardwood, covered on outside by $\frac{5}{8}$ x 62 x 40 in. steel plate. All hinges to be secured by bolts passing through to inside.

Ventilation:

3-in. or 4-in. globe ventilator in roof. Ventilator holes to be cut in foundation.

Cost

For storing 1,000 lb., size 6 x 6 ft.	$ 80 to $120
For storing 2,000 lb., size 6 x 7 ft.	100 to 160
For storing 3,000 lb., size 7 x 7 ft.	120 to 180
For storing 4,000 lb., size 7 x 8 ft.	140 to 200
For storing 5,000 lb., size 8 x 8 ft.	160 to 240

Distance from ground to floor, 3 feet. From floor to eaves, 6 feet.

Brick Magazine. These have 8 in. walls, have floors of and are lined with $\frac{7}{8}$-in. plank, and have roof covered with corrugated galvanized iron.

Cost

For storing 1,000 lb., size 7 x 6 ft.	$120 to $160
For storing 2,000 lb., size 7 x 7 ft.	140 to 200
For storing 3,000 bl., size 7 x 8 ft.	160 to 220
For storing 4,000 lb., size 7 x 9 ft.	180 to 260
For storing 5,000 lb., size 7 x 10 ft.	200 to 280

SECTION 39

FIRE EQUIPMENT

Chemical Engines. This engine, Fig. 161, has proved to be a most valuable piece of fire fighting apparatus for use in warehouses, factories, lumber yards, private residences, etc.

The construction consists of a forty gallon steel cylinder, tinned inside and out, set up on two suitable wheels 42 inches in diameter, either of the sarvan or all steel wide tire pattern, the cylinder being properly balanced between the two wheels

Fig. 161. Chemical Engine.

so that when the engine is set upright on its bottom the wheels clear the floor or ground; suitable handles are provided by which the engine is easily run from place to place and when required for village fire department use a suitable drag rope is furnished.

The equipment consists of 50 ft. ¾ in. chemical hose with couplings and shut-off nozzle. Dimensions, height 52 inches, diameter 16 inches, width over hubs of wheels 35 inches, track 29 inches.

Finished in aluminum, bronze or any color Japan.

Charge consists of 17 lb. bi-carbonate of soda and 10 lb. sulphuric acid.

The price of this engine, lead lined is $100 net.

A fire extinguisher similar to the one shown in Fig. 163 is

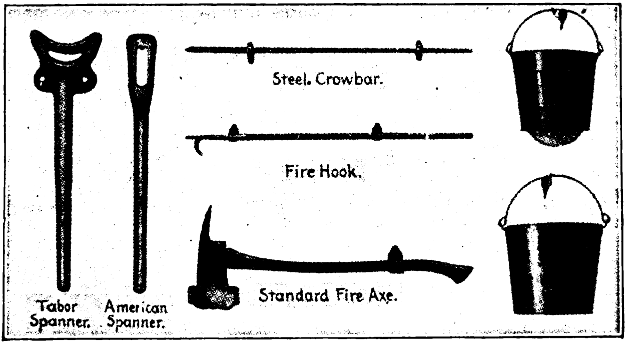


Fig. 162. Standard Underwriter Equipment.

made of copper and is tested to 350 lb. pressure. The 3 gal. size costs $13.00 net. An extra charge for this extinguisher costs $0.50.

Carbon Tetrachloride fire extinguishers are made in several

Fig. 163. Fire Extinguisher.

sizes. One having a capacity of 1¼ quarts costs $12, an extra charge costs $1.85. 1¾ quarts capacity $16, extra charge $2.50.

One gal. can of fluid $5.00. These extinguishers are made of brass and are worked by a pump handle

STANDARD UNDERWRITER EQUIPMENT

(As illustrated in Fig. 162.)

	Price net
Steel crowbar	$1.25 each
Fire hooks	1.50 each
Fire axe	2.25 each
Hose spanners	.35 each
Galvanized iron pails, 10 qt.	6.00 doz.

Linen Fire Hose tested to 500 lb. pressure, in 50 ft. lengths with couplings costs as follows:

Size in inches	Price per ft.
1	$0.26
1¼	.37
1½	.43
2	.52
2½	.62

Cotton Rubber Linen Hose costs as follows:

Size in inches	Price per ft.
1	$0.28
1¼	.32
1½	.35
2	.38
2½	.56

Fig. 164. Linen Fire Hose.

Hose Racks are made in various styles and finishes. An iron rack costs about $7.00.

SECTION 40

FORGES

A small rivet forge of the lever type weighs 80 lb., and costs with hood $14.50. A similar forge operated by a crank gear costs $25.00.

A larger forge similar to the one shown in Fig. 165 is suitable

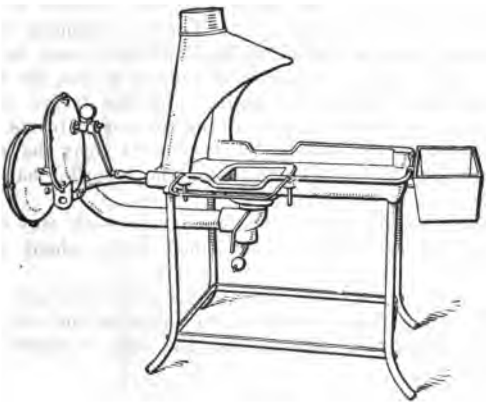


Fig. 165. Forge.

for horse shoeing and small repair work. These forges are made in a wide variety of styles and sizes and cost from $40 to $60. They weigh from 200 to 400 lb.

SECTION 41

FORKS

Stone or Ballast Forks. Net prices for extra grades stone or ballast forks in quantities, at Chicago, are as follows:

No. tines	Length Tines (in.)	Width Fork (in.)	Weight per doz. (lb.)	Price per doz.
8	13½	11¼	76	$20.00
10	13½	14½	88	25.00
12	14½	13¾	96	29.00

The above prices are for forks with natural finish, wide strap ferrules and heavy caps, with wood "D" ash handles.

SECTION 42

FORMS

Building, light wall and foundation, and column steel forms may be either purchased or leased. For miscellaneous work such as foundation construction or house building it may be economical to purchase a suitable outfit of moderate size, as the forms can be used over and over again. For the larger jobs it is usually more economical to lease the necessary forms.

Building forms for contact surface work may be rented at about $0.25 per sq. ft. This includes the labor of handling the forms on the work.

Steel forms for light wall and foundation work may be rented, and cost, together with the furnished labor, about $1.00 per sq. ft.

Column forms used with flat slab construction are rented at $21.00 per column form including the labor on the job. For use with beam and girder construction the cost is about $18.

SECTION 43

FURNACES AND KETTLES

(See Asphalt plants.)

A gasoline lead or leadite furnace (Fig. 166) is made in several sizes. The small size furnace has a gasoline capacity of 4 gal., the pot has a capacity of 200 lb.; it is fitted with three

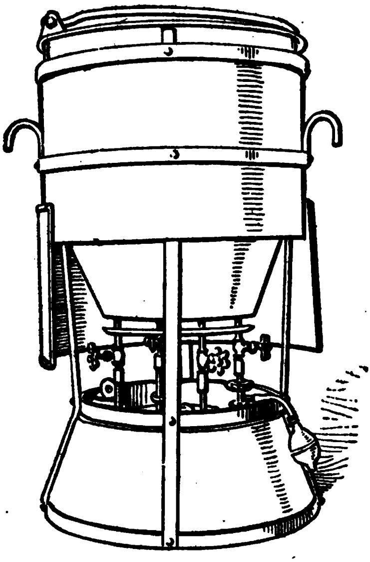


Fig 166. Gasoline Furnace.

burners and costs $52.00 f. o. b. factory. A larger size has a gasoline capacity of 6 gal.; it has a pot capacity of 325 lb. of lead or 50 lb. of leadite; it weighs approximately 170 lb. for shipment and costs $54.00 f. o. b. factory.

A lead melting furnace similar to the one shown in Fig. 167 is made in the following sizes. The price includes pot, bar, grate and ladle.

Capacity in lb.	Price	
	On wheels	On legs
200	$48	$33
450	57	40
700	73	50

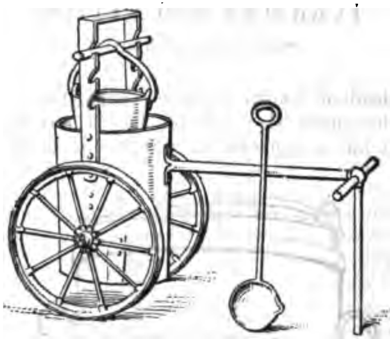


Fig. 167. Lead Melting Furnace.

Fig. 168. Kerosene Furnace.

Pressed steel pouring pots are made in sizes of from 50 to 125 lb. capacity and cost from \$4.50 to \$7.00. Heavy cast iron melting pots are made in sizes of from 200 to 700 lb. capacity and cost from \$6.00 to \$16.00.

A portable kerosene lead melting furnace (Fig. 168) costs as follows:

Capacity of pot in lb.	Oil consumption gal. per hr.	Approximate shipping weight in lb.	Price f. o. b. factory
200	1	395	\$115
450	1⅛	410	125
850	2	513	150

Fig. 169. Tar Heating Kettle.

Tar Heating Kettles. Cost as follows:

2 WHEEL KETTLE

Capacity in gal.	Approximate shipping weight in lb.	Price f. o. b. factory
50	800	\$150
100	1,140	180
150	1,140	200

4 WHEEL KETTLE

200	2,225	\$300
300	2,425	315
500	4,400	465

A pouring pot having a capacity of 4 gal. with an 8-in. spout is priced at \$6.00.

SECTION 44

GRADING MACHINES

(See also Elevating Graders.)

Machines which move earth by sliding or rolling over the ground and by either pushing the earth before them or into them by a combination of the two actions, thereby conveying the earth to the place of deposit, are known variously as scrapers, road machines, graders, spreaders, levelers, etc., and are of many types.

The commonly used scrapers are of three kinds: wheel, drag and buck or Fresno. In all three, as in the case of all scrapers and levelers, except where the soil is very sandy and loose, the earth must first be loosened by plows or picks. In the three kinds of scrapers the cutting edge of the machine digs into the soil, thereby loading itself, and the drag scraper slides over the ground carrying its load, the wheel scraper rolls along carrying its load and the Fresno scraper both drags, and carries and pushes a load in front of it.

Drag scrapers are efficient for a short distance only, from 50 to 100 feet, while Fresno scrapers can be used economically up to about 275 feet, when wheel scrapers should be substituted. The drag scraper is pulled by two horses and the driver dumps the scraper as well as drives. An extra man is usually needed for loading. In the case of the Fresno scraper, which is usually pulled by three or four horses, the driver is able to both load and dump the machine and to spread the earth to the proper depth while dumping it. The wheel scraper, however, needs a loader and an extra snatch team at the pit.

Wheeled Scrapers. The theoretical capacities of wheeled scrapers cannot be attained in actual work, the actual being about one-half.

Capacity cu. ft.	Weight in lb.	Price f. o. b. factory
7	400	$58
9	500	62
12	650	70
15	700	75
16	800	83

Repairs. Six new wheel scrapers: first cost, $45.00 to $50.00. Repairs for 6 months averaged $2.50 per scraper per month; life, 4 years. Second-hand wheel scrapers, original cost $45 00 to $50.00. Repairs, blacksmith at $3.50 per day over a period of 8 months, averaged $3.50 per scraper per month; life, 4 years.

Fig. 170. Wheeled Scraper.

These scrapers were two or three years old when these data were collected.

Drag Scrapers likewise hold about half the listed contents.

Capacity cu. ft.	Approximate weight in lb.	Price f. o. b. Ohio
3	78	$8.00
5	94	8.50
7	100	9.75

Fig 171. Drag Scraper.

Double Bottom Drag Scrapers

5½	110	$14
4½	105	13
3½	100	12

Prices of the double bottom scrapers are f. o. b. Chicago.

Fresno Scrapers. This type of scraper is ideal for building railroad embankments from side ditches and for wasting earth taken

from cuts when the earth is free from large stones and roots. It has been the author's experience that if the scraper is pulled at right angles to the line of the plow furrows the loading will be completed in a much shorter time than when the scraper is pulled parallel with the furrows.

No. 1, 5-foot cutting edge, capacity 18 cu ft., weight 300 lb.	\$28.50 to \$30.50
No. 2, 4-foot cutting edge, capacity 14 cu. ft., weight 275 lb.	28.00 to 30.00
No. 3, 3½-ft. cutting edge, capacity 12 cu. ft., weight 250 lb.	27.50 to 29.50

The listed capacity of the Fresno Scraper has been found by the author to be about twice the actual place measure capacity.

The following notes, covering an exhaustive examination of economic scraper work, are from an article by the writer in *Engineering and Contracting*, 1914. The prices, wages and costs are of that year.

The Economic Handling of Earth by Wheel and Fresno Scrapers. The cost of earth moving is a substantial factor in the total expense of nearly all construction work, and a considerable part of all earth moving operations is for work where it is not economical to use locomotives and cars, either because of the length of haul or because the magnitude of the work is not sufficient to justify the preparatory costs of a large plant. Under such conditions a choice must be made between wagons or carts and one or more of the various types of scraper.

A careful study and analysis of scraper work was made under the direction of the writer by Mr. A. C. Haskell for the Construction Service Co. of New York, and the results are given below to enable those who have scraper work to make rapidly and conveniently those computations without which no work of this kind can economically be done. The general economic formula for transportation is as follows:

Symbol	Factor
C	The total expenses per day in cents.
w	The net load, for the average trip, in pounds, or other convenient unit.
S	The speed (average) when loaded, in feet per minute.
KS	The speed (average) when returning, in feet per minute.
D	The length of haul in feet.
l	The time lost in turning, resting, and wasted for an average round trip, in minutes.
Rt	The total cost in cents per ton for transportation.
W	The number of minutes in the working day.

The following facts are deducible algebraically:

$\frac{D}{S}$ ....Time for a loaded trip, in minutes.

$\frac{D}{KS}$ ....Time for the empty haul.

$l + \dfrac{D}{KS}$ ....Actual time not occupied in transporting material, in minutes.

$\dfrac{D}{S}\left(1 + \dfrac{1}{K}\right) + l$ .....Average time for one round trip, in minutes.

$\dfrac{W}{\dfrac{D}{S}\left(1 + \dfrac{1}{K}\right) + l}$ .....Average number of trips per day. This value must be an integral quantity, for the average work for any one day.

$\dfrac{Ww}{\dfrac{D}{S}\left(1 + \dfrac{1}{K}\right) + l}$ .....Average total amount transported per day.

$R = C\dfrac{\dfrac{D}{S}\left(1 + \dfrac{1}{K}\right) + l}{Ww}$ Cost of transportation per pound, or other convenient unit.

The value for C will depend upon the number of horses used in a team, whether extra teams are employed in loading, the general organization of the gang, and to a lesser extent on the cost of repairs and depreciation of the scrapers themselves. The value w of the net load will depend entirely upon the type and size of equipment, and the care with which loading is done. It is likely to vary much more with wheel scrapers than with Fresnos. In heavy ground which has not been well loosened, particularly where there are many roots of trees and occasional boulders, the wheel scrapers often fail to get more than a 60% or 70% load. The value for w was determined by taking the average of several hundred trips, the amount of each load being estimated by the inspector on the basis of the space occupied loose, multiplied by a density factor and afterward checked by the place measure computations. The check on the wheeler capacity was not so accurate as that with the Fresnos, in which case the computed amounts from several cellar excavations checked the estimated loads within 5%.

In a well organized scraper gang the speed loaded and that light are fairly constant for constant conditions, changing as soon as the local conditions vary. These conditions are the wetness of the ground hauled over, the "sea room" available for each team and the grades and curvatures along the line of haul. The length of haul is nearly always a constantly varying quantity. Its average value was determined by measuring it at regular intervals, and averaging the figures thus obtained. The time lost in turning, loading, etc., varies somewhat but for a given set of con-

ditions was taken as an average of a large number of observations. The data obtained in this way by an inspector who timed scrapers for two hours or so each day were afterward compared with a count kept by a boy with a tally machine at the dump, resulting in very close agreement, except that the average costs obtained by the time study method were nearly always a few per cent less than the probable actual costs kept by the tally boy over the whole day's work. The main reason for this seemed to be that when under the eye of an inspector with a watch in one hand and a note book on his knee the drivers keep their teams going a little faster when not loaded and are a little more prompt in dumping and turning than when observed by a boy.

In the following tables the columns headed "Transportation Cost" show the cost for actually moving the material, while the columns entitled "Static Cost" are for the cost of waiting at the loading point, loading, dumping and miscellaneous delays. No account is taken of extraordinary delays, such as breakdowns, etc.

Wheel Scraper Work. The following observations of wheel scrapers cover a period of some three months and were made under various conditions.

The wheel scraper is a modified form of the drag scraper, being suspended between two wheels in such manner that the pan drags along the ground when loading and then, when full, may be raised by a system of levers, so that it rides suspended several inches above the ground. The operation of loading ordinarily requires the assistance of a two or three-horse snatch team and driver, and a "loader" whose duty it is to lower the pan, guide it while being filled and to raise it when full. At the dumping point the pan is unhooked and lowered and the dumpman by an upward thrust upon the attached handle causes the pan to make a quarter turn, thus dumping and partially spreading the material.

Distinction has been made between wheelers in loam, clayey loam (Table I), etc., and wheelers in sand, fine gravel, etc., owing to the fact that the nature of the soil materially affects the size of the load, and consequently the speed of transportation more or less. Although it may take less time to get a full load in soft sand, it usually takes more time to get started after the snatch team has been unhooked owing to the wheels being deeply buried. And during transit the sand will waste much more than the loam, so that the load actually dumped is considerably less.

In Table I column 12 gives values of *R* in the transportation formula.

From Table I it will be seen that the average cost per cubic yard was 6.2 ct. for the fixed or static cost, which includes cost

of loading, dumping and idle time, and 4.1 ct. per 100 ft. of haul for the transportation cost, based on the time study figures.

TABLE I.—WHEEL SCRAPERS IN LOAM AND CLAYEY LOAM.

(Arranged in order of static charge.)

No.	Sc.	D.	D'.	S.	KS.	K	Load C. Y.	1 Min.	Loading time, secs. (included in static cost).	Other "1" time, sec.	Total cost (1914 figs.) Cts. per cu. yd.	Static cost, cts. (1914 figs.)	Transp. cost (1914 figs.) Cts. cu. yd.	Transp. cost per 100 ft. haul (1914 figs.) Cts. cu. yd.
	6...	385	445	212	233	1.06	0.38	1.10	26	40	15.2	3.9	11.3	3.0
	5...	190	225	208	225	1.08	0.37	1.23	28	46	11.0	4.3	6.7	3.5
	5...	525	525	194	232	1.20	0.33	1.03	30	32	23.2	4.3	18.9	3.6
	5...	345	345	218	218	1.00	0.31	1.00	30	39	16.5	4.5	12.0	3.5
	5...	235	285	142	197	1.38	0.41	1.24	31	43.5	14.5	4.7	9.8	4.2
	7...	530	530	182	230	1.26	0 37	1.41	26.2	58.5	23.6	5.0	18.6	3.5
	5...	350	350	206	232	1.13	0.33	1.26	32	43.5	16.7	5.3	11.4	3.3
	7...	570	570	222	260	1.17	0.37	1.48	25.3	63.3	23.0	5.5	17.5	3.1
	4...	350	350	226	312	1.38	0 33	1.10	34.2	32.0	18.5	5.5	12.0	3.4
	5...	330	400	222	238	1.07	0.39	1.58	39	56	18.6	6.2	12.4	3.8
	7...	325	520	206	255	1.24	0.30	1.54	19.3	73.2	22.8	6.8	16.0	4.9
	4...	125	190	268	150	0.56	0.42	2.05	34	89.0	15.2	8.3	6.9	5.5
	6...	275	625	216	244	1.13	0.30	1.89	21.2	92.4	27.0	8.9	18.1	6.6
	4...	195	195	197	240	1.22	0.35	1.90	36.8	77.1	18.0	9.2	8.8	4.5
	7...	250	380	218	216	0.99	0.30	2.23	17.9	115.9	23.0	10.0	13.0	5.2
Min.	4..	125	190	142	150	0.56	0.30	1.00	17.9	32.0	11.0	3.9	6.2	3.0
Av.	5.5..	332	395	209	232	1.11	0.35	1.54	28.7	60.1	19.1	6.2	12.9	4.1
Max.	7..	570	625	268	312	1.38	0.42	2.23	39.0	115.9	27.0	10.0	18.9	6.6

In the above table abbreviations are as follows:

No. Sc. ....Number of scrapers at work in gang.
D ....Length of loaded haul, feet.
D' ....Length of empty haul, feet.
S ....Rate of travel, loaded, feet per minute.
KS ....Rate of travel, empty, feet per minute.
K ....Ratio of empty speed to loaded speed.
Load C. Y. ....Size of load carried in cubic yards place measure.
1 ....All time except that in actual transit to or from dump.
Other "1" time ......Other lost or idle time; that in addition to loading time.

The observations in Table II were made where a road had been cleared through the woods. The soil, a rich loam, was more or less interspersed with roots, to extricate which required the labor of two men. In this instance the static cost is high, due in a measure to the time required to load. Owing to the roots running through the soil sometimes it was necessary to make more than one attempt to load, but good full loads were obtained, which is really more essential than saving a few seconds and starting for the dump with a half loaded scraper.

The principal thing to be called to attention here, however, is a fault very frequently observed, the wrong apportionment of scrapers to length of haul. In this case there were too many for so short a haul, thereby causing frequent delays both at the loading point where they became bunched and en route to the dump, which forced up the static cost. The rate of progress in transit was also reduced, especially on the return from the dump, as is shown by *KS*, when the teams were obliged to slow down to allow those ahead room to turn, load, etc. This is a state of affairs which should never be permitted; scrapers should maintain a steady progress in both directions, and at no time should a scraper be obliged to wait idle at the loading point for the ones ahead to be loaded.

TABLE II.—WHEEL SCRAPER WORK, LOAM, OBSTRUCTED BY ROOTS.

	Loading.		Transporting loaded.		Transporting empty.		Delays, including dumping.	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
	0	38	0	20	1	22	1	00
	0	27	0	18	0	57	2	18
	0	37	0	31	1	30	1	47
	0	38	0	23	1	06	1	11
	0	33	0	20	0	59	1	41
	0	27	0	31	1	23	1	33
	0	30	0	21	1	20	1	15
	0	45	0	53	1	24	2	01
	0	39	0	35	1	28	1	14
	0	34	0	27	1	10	1	04
Av.	0	34	0	28	1	16	1	29

D—Loaded haul	125′
D′—Empty haul	190′
S—125′ 28 sec.	268 ft. per min.
KS—190′ 1 m., 16 s.	150 ft. per min.
K—150/268	0.56
l	2 min., 03 sec.
D/S + D′/KS	1 min., 55 sec.
w	0.425 cu. yd.
C	40.95/4 = 1024 ct.
W	600 min.

4 scrapers at $5.50	$22.00
1 snatch team and driver	7.50
1 loader	2.25
1 dumpman	1.65
1 waterboy	1.00
1 foreman	6 55
	$40.95

$$R = \frac{1024}{600} \times \frac{3.77}{0.425} = 15.2 \text{ ct per cu. yd.} = 8.3 \text{ ct. static cost} + 5.5 \text{ ct. per } 100' \text{ haul.}$$

The observations in Table III were taken where the top soil was very dry, clouds of dust being raised at each attempt to fill a scraper.

Both the static cost and the transportation cost per 100 ft. of haul are excessive. The former is due partially to the time wasted at the dump, which observation showed to be prolonged beyond all necessity. Drivers were wont to stop, take long turns about, etc., when really there was no need of stopping at all, and the scraper should have been turned about immediately

TABLE III.—WHEEL SCRAPER WORK IN VERY DRY LOAM (1914).

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping.		Transporting empty.		Delays.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0	33	0	31	1	26	0	17	2	31	0	25
0	35	0	20	1	03	1	10	2	05	0	35
0	43	0	23	1	21	0	20	2	38	.	..
0	44	0	14	1	24	0	26	2	49	0	25
0	44	0	18	1	07	0	15	2	44	0	30
Av.0	39.8	0	21.2	1	16.2	0	29.6	2	33.4	0	23

D—Loaded haul .....275′
D′—Empty haul ....625′
S—275 1 m. 16.2 s....216′ min.
KS—625 2 m. 33.4 s...244 min.
K—244/216 ....1.13
l .... 1 min. 53.6 sec.
D/S + D′KS .... 3 min. 49.6 sec.
w ....0.296 cu. yd.
C—5030/6 ....838.33 ct.
W ....600 min.

Cost of 6 scraper gang ...$50.30

$$R = \frac{838.33}{600} \times \frac{5.72}{0.296} = 27.0 \text{ ct. per cu. yd.} = 8.3 \text{ ct. static cost} + 6.6 \text{ ct. per } 100' \text{ haul.}$$

after dumping, in the shortest possible radius. The excessive transportation cost per 100 ft. haul, to which may be directly traced the high cost per cubic yard, was owing to the extremely long empty haul D' as compared to the loaded haul D, whereby considerable time was consumed. The haul should always be the shortest route to the dump, and the return, if it is not feasible to use the same route, should be as direct as possible. The loads were small, due to the dry, dusty nature of the material, which could not be heaped, and wasted considerably en route to the dump, which, of course, runs up both static and transportation costs.

The observations of Table IV were made where a gang was removing top soil from a piece covered with tall weeds, the roots of which prevented full loads. The soil was dry and dusty.

Here is another example of too many scrapers for the length of haul. This fact, combined with the small loads, produced the high costs. The time "Waiting and Preparing to Load" is altogether too high. The speed KS on the return is less than S loaded speed. When this state of affairs exists it can invariably be traced to too many scrapers, for they become bunched about the loading point and the returning drivers, seeing this, slow down, thus wasting considerable time.

In the formula, $R = C \dfrac{D/S(l + l/k) + l}{W.W}$ all the quantities

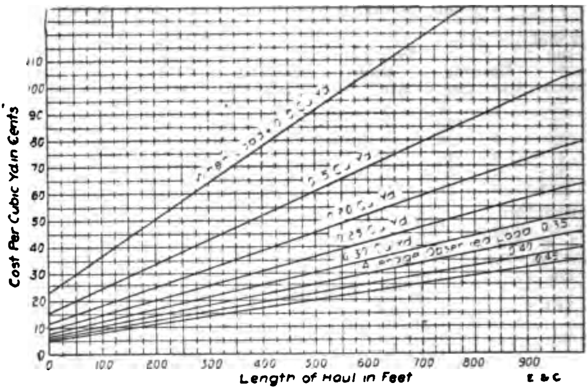


Fig. 172. Curves Showing Costs Per Cubic Yard of Handling Loam and Loam Clay with Wheel Scrapers for Various Sizes of Load and Length of Haul (1914 Figures).

TABLE IV.—WHEEL SCRAPER WORK IN DRY SOIL FULL OF TALL WEEDS (1914).

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping.		Transporting empty.		Delays.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	18	0	19	1	10	0	35	1	40	.	..
2	08	0	15	1	26	0	26	1	56	.	..
1	25	0	16	1	20	0	14	2	05	0	10
0	11	0	14	1	00	0	14	1	48	0	59
0	29	0	14	1	01	0	34	1	22	.	..
1	52	0	16	1	10	0	27	1	52	0	13
1	28	0	22	1	01	0	39	1	45	.	..
1	05	0	24	0	54	0	33	1	36	.	..
1	38	0	23	0	59	0	18	1	37	.	..
2	10	0	16	1	24	0	13	1	52		..
Av.1	22.4	0	17.9	1	08.5	0	25.3	1	45.3	0	8.2

D ....250′
D′ ....380′
S—250, 1 min., 08.5 sec... 18 per min.
KS—380, 1 min., 45.3 sec.216 per min.
K—216/218 .... 0.99
l ....2 min. 13.8 sec.
D/S + D′/KS ....2 min. 53.8 sec.
w ....0.296 cu. yd.
C—5580/7 ....797 ct.
W ....

Cost of 7 scraper gang.....$55.80

$$R = \frac{797}{600} \times \frac{5.13}{0.296} = 23.0 \text{ ct. per cu. yd.} = 10 \text{ ct. static} + 5.2 \text{ per 100-ft. haul.}$$

DATA USED IN CALCULATING CURVES FIG. 172 FOR WHEEL SCRAPERS IN LOAM AND CLAYEY LOAM (1914 Figures).

C	896 cts.	D	Varies.
w	Varies.	S	209 ft. min.
l	1.54 min.	K	1.1
W	600 min.	l/K	0.91

Value for C for 5-scraper gang determined as follows:

10 mules at $1.75	$17.50
5 drivers at $1.95	9.75
1 loader at $2.25	2.25
1 dumpman at $1.75	1.75
1 3-mule snatch at $5.25	5.25
1 3-mule snatch driver at $2.25	2.25
1 D. R. at 3% per month	1.07
Foreman at $4.00	4.00
Waterboy at $1.00	1.00
Total	$44.82
Per scraper	8.96

Value of scraper	$48.00
Value of harness	50.00

$$R = \frac{1}{w}\left[\frac{C.\,D\,(1 + 1/k)}{S\,W} + \frac{1\,C}{W}\right] = \frac{1}{w}\left[\frac{896 \times 1.91\,D}{209 \times 600} + \frac{1.54 \times 896}{600}\right]$$

$$= \frac{1}{w}\left[0.01365\,D + 2.30\right]$$

w.	Costs D = 100′	Costs 500′	Costs 1000′
.10	36.65	91.25	.....
.15	24.43	60.83	106.33
.20	18.32	45.62	79.75
.25	14.66	36.50	63.80
.30	12.22	30.42	53.17
.35	10.47	26.07	45.57
.40	9.16	22.81	39.87
.45	8.14	20.28	35.44

may have fixed values determined from observation assigned to them, except *W* and *D*, the load and haul, which will vary according to the kind of scraper employed and the nature of the work.

Curves, Fig. 172, may be drawn showing costs for varying loads and lengths of haul.

The observations of Table V were made where the material was a mixture of sand and loam, without enough of the latter, however, to lend stability to the whole. Boulders were numerous, often interfering with the obtaining of good loads.

The above costs are a good example of how conditions affect results, and the above method of analysis readily shows this. The static cost, 8.4 ct. per cubic yard, is somewhat above the average, due partly to the boulders making loading difficult, and partly to the small loads carried to the dump. But it is the high transportation cost which attracts attention. This was due to the road to the dump being exceedingly rough and muddy after

TABLE V.— WHEEL SCRAPER WORK IN SANDY LOAM (1914).

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping and turning.		Transporting empty.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0	45	0	28	3	37	0	15	2	50
1	02	0	15	3	03	0	15	3	02
0	40	0	16	3	12	0	12	3	10
1	10	0	14	3	16	0	33	2	59
0	50	0	20	3	00	0	15	2	45
Av.0	53.4	0	18.6	3	13.6	0	18	2	57.2

D	585′
D′	625′
S—585, 3 min. 13.6 sec.	181′ per min.
KS—625, 2 min. 57.2 sec.	212′ per min.
K—212/181	1.17
l	1 min. 30 sec.
D/S + D′/KS	6 min. 10.8 sec.
w	0.26 cu. yd.
C—7395/10	739.5 ct.
W	600 min.

10 scrapers at $5.50	$55.00
1 snatch	7.50
1 loader	2.25
1 dumpman	1.65
1 foreman	6.55
1 waterboy	1.00
	$73.95

$$R = \frac{73.95}{600} \times \frac{7.68}{0.22} = 43 \text{ ct. cu. yd.} = 8.4 \text{ ct. static} + 5.9 \text{ ct. per 100-ft. haul}$$

recent rains, the scrapers sinking at times almost to the hubs. The loads were consequently small, wasting away, and the rate of moving (*S* and *KS*) materially reduced. Observations were taken in the afternoon of the same day when a new and less

TABLE VI.— SCRAPER WORK IN COARSE SAND (1914)

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping and turning.		Transporting empty.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	05	0	37	2	59	1	04	2	48
3	20	0	17	2	35	1	07	2	06
4	08	0	14	3	14	1	12	1	56
1	05	0	.12	2	31	0	14	2	26
1	26	0	12	3	08	0	12	2	00
1	42	0	18	2	18	0	24	2	03
1	09	0	15	2	45	1	08	2	43
0	49	0	11	3	00	1	17	2	00
1	10	0	18	2	20	1	14	2	26
0	50	0	13	1	45	1	22	3	00
Av.1	40.4	0	16.7	2	39.5	0	56.4		21

D	585′
D′	610′
S—585, 2 min. 39.5 sec.	220′ per min.
KS—610, 2 min. 21 sec.	259′ per min.
K—259/220	1.18
l	2 min. 53.5 sec.
D/S + D′/KS	5 min. 00.5 sec.
w	0.26 cu. yd.
C—68.45/9	760.5 ct.
W	600 minutes

Cost of 9 scraper gang ...$68.45

$$R = \frac{760.5}{600} \times \frac{7.9}{0.26} = 38.5 \text{ ct. per cu. yd.} = 14.1 \text{ ct. static} + 4.2 \text{ ct. transportation per 100-ft. haul.}$$

difficult path was used, and the effect was shown directly, S increasing to 191 ft. per minute and *KS* to 234 ft. per minute, and the transportation cost being reduced 1.1 ct. per cubic yard.

The observations of Table VI were made where the material handled was a coarse sand with a sprinkling of loam.

In this instance the reverse of the last case cited is true. Here the transportation cost is normal, but the static cost (which shows fluctuations in cost due to all operations except actual transportation), is very high. Small loads were again responsible in part, but the chief reason was because of a long turn of about 220 ft. around a pool of water at the dump. The time consumed in making this extra long turn after the material had been dumped so increased *l*, the time when the scrapers are not actually engaged in the handling of material, that in consequence the static cost was excessive. It will be noticed in the time study that two or three of the scrapers turned about shortly without waste of time, and the foreman should have seen that all did likewise.

The observations of Table VII were made where the material was a coarse dry sand which wasted a great deal en route to the dump.

Observation has shown that high costs are more often due to

TABLE VII.—WHEEL SCRAPER WORK IN COARSE, DRY SAND, VERY LONG HAUL (1914).

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping and turning		Transporting empty.		Delays.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0	26	0	12	4	07	0	43	3	50	.	..
0	28	0	15	5	00	0	23	3	46	.	..
0	46	0	31	4	50	0	15	3	38	0	15
0	32	0	20	4	49	0	22	3	37	.	..
0	32	0	30	5	28	0	22	3	43	.	..
0	22	0	15	5	00	0	21	3	44	.	..
0	56	0	12	5	02	0	14	3	21	.	..
0	38	0	15	3	52	0	21	4	04	.	..
0	24	0	17	4	00	0	41	3	20	.	..
0	43	0	18	4	17	0	18	3	42	.	..
Av. 0	34.7	0	18.5	4	38	0	24	3	46.5	0	1.5

D = D′ =	1040′	9 scrapers at $5.50	$49.50
S—1040/4 min. 38 sec.	224′ min.	1 snatch and driver	7.50
KS—1040/3 min. 46.5 sec.	276′ min.	1 loader	2.25
K—276/224 1.23		1 dumpman	1.75
l	1 min. 18.7 sec.	1 shovelman	1.65
D/S (1 + ′/K)	8 min. 24.5 sec.	1 foreman	6.55
w	0.296 cu. yds.	1 waterboy	1.00
C—7020/9	780 ct.		
W	600 min.		$70.20

$$R = \frac{780}{600} \times \frac{9.72}{0.296} = 42.6 \text{ ct. cu. yd.} = 5.7 \text{ ct. static} + 3.5 \text{ ct. per 100-ft. haul.}$$

carrying poor loads to the dump than to any other cause. It will be noticed that in the gang a shovelman was employed whose duty it was to follow a scraper as it was being loaded and without delaying the progress of the work to fill up the scraper as much as possible. By this means the wedge-shaped space at the back of the scraper, invariably left empty when using a snatch team alone, was filled. Besides causing much larger loads to be delivered at the dump, the scheme prevented the drivers from standing in this space and riding the scrapers loaded, a thing frequently observed under the excuse that it was necessary to keep the scrapers balanced and prevent the material wasting out the front, but which should under no conditions be allowed. The material here was very soft, however, and a great deal wasted off, as the haul was rather long and rough. Front gates upon the scrapers would have made the retaining of the good loads produced by the shovelman's efforts possible, and correspondingly decreased the unit costs.

In order to plot curves for various loads and length of haul for wheel scrapers in sand, average values would be substituted in the formulas as follows, on the basis of a 5-scraper gang:

		w.	D = 100′	500′	1000′
C	896 ct.	.10	39.37	....	....
l	1.75 min.	.15	26.25	61.63	....
w	variable	.20	19.68	46.22	....
S	215 ft. per min.	.25	15.75	36.98	63.52
K	1.1	.31	12.70	29.82	51.23
1/K	0.91	.35	11.25	26.41	45.37
D	variable	.40	9.84	23.11	39.70
W	600 min.	.45	8.75	20.54	35.29

$$R = \frac{1}{w}\left(\frac{896 \times 1.91\,D}{215 \times 600} + \frac{896 \times 1.75}{600}\right) = \frac{1}{w}(0.01327\,D + 2.61)$$

The time studies given above show how important it is to have full loads and the proper apportionment of the number of scrapers to the length of haul. In order to make this latter point, which is of prime importance, more specific, one or two illustrations will be given to show: (1) How, if too few scrapers are at work upon a given haul, the addition of another will lessen the cost per cubic yard, and (2) if there is already a sufficient number at work to produce economical results, how the addition of one more may make the unit cost per cubic yard higher, and in addition may actually reduce the total amount of material handled.

The following observations were made where the material handled was a loam and clay mixture, rather sticky, but which loaded well and did not waste on the way to the dump. The

length of haul was about 325 ft. From 6:45 a. m. to 2 p. m., 6¼ hours, omitting one hour at noon, with four scrapers working, 330 loads were dumped = 110 cu. yd. at three loads to a yard.

4 scrapers at $5.50	$22.00
1 snatch team and driver	7.50
1 loader	2.25
1 dumpman	1.65
⅓ foreman	2.18
⅓ waterboy	0.33
	$35.91

Cost per cu. yd. $= \frac{6\frac{1}{4}}{10} \times \frac{3591}{110} = 20.4$ ct. per cu. yd. = 6.3 ct. per cu. yd. per 100-ft. haul.

At the above rate of handling $\frac{10}{6\frac{1}{4}} \times 330 = 528$ loads, or 176 cu. yd. would be dumped per 10-hour day.

From 2 p. m. to 5:45 p. m. 3¾ hours, with five scrapers working, 252 loads were dumped = 84 cu. yd.

Cost: As above, with addition of 1 scraper = 41.41.

Cost per cu. yd. $= \frac{3\frac{3}{4}}{10} \times \frac{4141}{84} = 18.5$ ct. per cu. yd. = 5.7 ct per cu. yd. per 100-ft. haul.

At above rate of handling $\frac{10}{3\frac{3}{4}} \times 252 = 672$ loads or 224 cu. yd. would be dumped per 10-hour day.

Thus it will be observed that the addition of a scraper in this instance was all for the better, as for an increase of 15% in cost, 27% more material would be handled per day at a decreased cost of 10% per cubic yard and 10.5% per cubic yard per 100-ft. haul.

Another instance was where a coarse sand was hauled about 325 ft. The loads were not very good and the costs were rather high, but the case serves well as an example of the point in view. From 6:45 a. m. to 12 m., 5¼ hours, with five scrapers working, 275 loads were dumped = 75 cu. yd. The cost was:

5 wheelers at $5.50	$27.50
1 snatch team and driver	7.50
1 loader	2.25
1 dumpman	1.65
⅓ foreman	2.18
⅓ waterboy	0.33
Total	$41.41

$$\text{Cost per cu. yd.} = \frac{5\frac{1}{4}}{10} \times \frac{4141}{75} = 29 \text{ ct.} = 8.9 \text{ ct. per cu. yd.}$$

per 100-ft haul.

At the above rate of handling, 525 loads, or 143 cu. yd. would be dumped per 10-hour day.

From 1 p. m. to 5:45 p. m, 4¾ hours, with six scrapers working, 324 loads = 88 cu. yd. were dumped.

Cost: As above plus one wheeler = $46.91.

$$\text{Cost per cu. yd.} = \frac{4\frac{3}{4}}{10} \times \frac{4691}{88} = 25.3 \text{ ct.}$$

= 7.8 ct. per cu. yd. per 100-ft. haul.

At this rate of handling 683 loads, 185 cu. yd., would be dumped per 10-hour day. Thus for an increase in cost of 13%, 29% more material would be handled per day, at a decreased unit cost of 18½% per cu. yd., and 14% per cu. yd. per 100-ft. haul.

It is not easy to comprehend at first glance the effects produced by having too many scrapers for a certain haul. It seems natural, without analysis, to suppose that the more scrapers there are working, the more work will be accomplished. Proof of this was evidenced by such conditions existing. In order to look more closely into the details of this case, it is worth while to present the complete time study, Table VIII. The material was

TABLE VIII.

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping and turning.		Transporting empty.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0	35	0	10	2	38	0	12	2	30
1	05	0	15	2	33	0	27	1	45
0	34	0	16	2	09	0	11	2	34
0	45	0	13	1	53	0	18	2	49
0	28	0	12	2	35	0	17	2	05
1	00	0	10	2	38	0	25	2	39
0	31	0	10	2	49	0	25	2	15
0	30	0	10	2	20	0	18	2	10
0	35	0	8	2	20	0	22	2	05
0	48	0	12	2	15	0	27	3	03
Av. 0	41.1	0	12.1	2	25	0	20.2	2	23.5

D .... 600 ft.
D′ .... 650 ft.
S .... 248 ft. min.
KS .... 272 ft. min.
K .... 1.10.
l .... 1 min. 13.4 sec.
D/S + D′/KS .... 4 min. 48.5 sec.
w .... 0.30 cu. yd.
C .... 820.7 ct.
W .... 600 min.

Cost of 7 scraper gang ..$57.45

R = 820.7 × 6.03 = 27.4 ct. per cu. yd. = 5.5 ct. per cu. yd. static + 3.65 ct. per 100-ft. haul.

a mixture of clay and sand, with enough of the latter to cause it to break up well when plowed. Seven scrapers were at work.

At the above rate of hauling 210 cu. yd. of material would be dumped per 10-hour day.

The observations in Table IX were made when eight scrapers were working in the same material and hauling to the same distance.

At the above rate of handling $\frac{600}{7.03} \times 8 \times 0.3 = 205$ cu. yd. will be dumped per day.

Thus, be it observed, actually less material was handled with eight scrapers than with seven, so that in consequence the unit costs per cubic yard were higher. This result was due to the fact that the time lost at the loading point was nearly doubled (compare time studies) owing to the scrapers getting bunched up there and being obliged to await their turn to be filled with the snatch team; the time of transportation was materially increased owing to the enforced reduction of the rate of traveling due to overcrowding, so that the time necessarily lost by the gang due to this congestion more than overbalanced the extra amount of material which an additional scraper would ordinarily handle.

TABLE IX.

Waiting and preparing to load.		Loading.		Transporting loaded.		Dumping and turning		Transporting empty.	
Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	40	0	15	2	53	0	19	2	23
1	55	0	15	2	33	0	25	2	32
0	42	0	13	2	44	0	25	2	15
2	20	0	30	3	00	0	27	2	43
1	49	0	21	2	30	0	27	1	45
0	53	0	19	1	55	0	18	2	00
1	13	0	14	2	31	0	19	2	41
0	31	0	12	2	39	0	18	2	30
0	39	0	10	2	54	0	22	3	15
0	55	0	16	2	47	0	25	2	40
Av.1	15.7	0	16.5	2	38.6	0	22.5	2	28.4

D .... 600′
D′ .... 650′
S .... 226′ per min.
KS .... 262′ per min.
K 1.16
l .... 1 min. 54.7 sec.
D/S + D′/KS .... 5 min. 7 sec.
C .... 787 ct.
w .... 0.30 cu. yd.
W .... 600 min.

Cost of 8 scraper gang $62.95

$$R = \frac{787}{600} \times \frac{7.03}{0.30} = 30.7 \text{ ct. per cu. yd.} = 8.3 \text{ static} + 3.7 \text{ ct. per 100-ft. haul.}$$

The above presents a typical example of conditions very frequently observed, conditions for the existence of which there is no excuse, especially when the work is being carried on under the supervision of a man of long experience in such work, who, if he opened his eyes to facts and took an interest in his work, could not help but determine what constitutes the efficient handling of his gang. But experience has proved that the great majority of foremen do not take enough interest to sit down after working hours and figure out how the efficiency of their gang may be increased during working hours. Scraper work may be divided into the following: Loading, transporting and dumping. Each of these operations is distinct in itself and yet each so depends upon the others that if there is any flaw in one the whole work must show the effect. For example, a few moments' observation of a piece of work shows that the scrapers are constantly in motion with no idle time at the loading point except that required to turn and get into position for loading and the progress to and from the dump is brisk, but there are periods when the snatch team is idle for several minutes waiting for a scraper to load and the dumpman sits idle upon his shovel.

Again, if the loading team is hooking into one scraper after another in rapid succession and the dumpman has no sooner spread one scraper load than the next team comes along, but gathered around the loading point idly awaiting their turn to be loaded are several scrapers, the drivers laughing and joking, the horses nosing about on the ground, the progress to the dump reduced because of congestion, is it not self-evident that too many scrapers are on the work and enough should be taken off to keep them moving all the time? When things are going briskly the entire atmosphere of the work is charged with energy, felt alike by man and beast, but when obliged to wait for minutes at a time in idleness a feeling of inertia pervades the work which, in its results, it must necessarily reflect. Keep everything in motion. See that the loader, snatch team, and dumpman are kept busy, that the scrapers are continually on the move, and work will be performed economically. Have regular intervals for letting the whole gang rest, if necessary, but while at work let each individual unit of the whole be performing its function to the best of its capacity.

The greatest trouble with wheel scrapers is likely to be caused by the heavy pressure on the collars of horses and mules, due to loading in heavy ground. For this reason the collars should be made to fit as perfectly as possible, and the animals examined every night for sores on the necks or withers.

When loading wheelers with a snatch team the chain should

be hooked to a point as near as possible to the scraper itself, otherwise the pull of the snatch team will throw a heavy load on the backs of the wheeler team.

The working speed of a team is such that when heavily loaded the team proceeds a little more slowly than the ordinary man will walk, but when "light," horses (more than mules) are apt to move faster than the ordinary walking gait of the driver. Consequently it is a good plan to require all drivers to ride in the scraper (which can be done with wheelers, but not with Fresnos) when light, and never to sit on the loaded scraper.

When dumping a wheel scraper it is important, so far as possible, to have the team on ground at least as high as that on which the scraper rests. Otherwise the heavy load that always comes on the collar or saddles by the act of dumping will be increased by gravity, often to the great distress of the animals.

In loading a scraper, care should be exercised not to allow the team to pull it farther and overload it after it is once full, since such extra effort is utterly useless and is very exhausting. Conversely, each load should be a full one. The first mark of a badly handled job is improper and variable loading of the vehicles.

It should be borne constantly in mind when laying out and directing earth moving work with small equipment that the "normal haul" for a wheel scraper is longer than for a Fresno and shorter than for a one-horse cart.

Fresno Scraper Work. With this type of equipment, each scraper is hauled by from two to four horses, or mules, depending upon its capacity; but the services of a snatch team and driver and usually of a dumpman, regularly required for wheel scraper work, may be dispensed with. The salient features of the Fresno are the speed and ease with which it can be loaded and dumped and also its much lower first cost. The capacity of the Fresno ordinarily hauled by three horses is from 7 to 8 cu. ft. as against a capacity of 9 to 10 cu. ft. for the No. 2½ wheelers. As mentioned at the beginning of this paper, in comparing two methods to determine the more economical for the handling of material it boils down to a question of amount carried and speed of handling. Now, it is evident that of two methods of practically equal cost of operation if one is sufficiently more speedy than the other it will do work more economically even though handling less material per unit. On the other hand there may come a point where the haul gets so long that the advantage gained in speed of loading and dumping (the time consumed in transit of course assumed as being the same in both instances) will be overcome by the fact that the other method handles more material.

For example, assume, Table X, two gangs, one composed of five Fresno scrapers and one of five wheel scrapers. For this gang the unit cost per scraper is practically the same, say 900 ct. For each round trip the wheeler loads in 1½ minutes and dumps and turns in ½ minute. The Fresno loads in ½ minute and dumps and turns in ¼ minute. Then in the formula,

$$y = \frac{CD/S\,(l + l/K) + l}{W\,w}.$$

The Fresno is not suitable for work including many roots or boulders, and is not generally used with snatch teams for loading. When the ground is too hard for Fresno loading it may not be too hard to be loaded by wheelers and snatch teams, but where the haul is short it is generally much more economical to loosen

TABLE X.

	Wheelers.	Fresnos.
D	220′	220′
S	220′ per min.	220′ per min.
KS	220′ per min.	220′ per min.
K	1	1
l/K	1	1
l (1½ + ½)	2 min. (½ + ¼)	0.75 min.
D/S (1 + l/K)	2 min.	2.00 min.
W	600 min.	600 min.
w	⅓ cu. yd.	¼ cu. yd.
C	900 ct.	900 ct.

it with a plow and haul with Fresnos than to use the wheelers. The purpose of this paper is mainly to show comparisons between methods where both or all are possible, but when one and one only can be economic. For hauling the material up heavy grades, such as a railway embankment, the Fresno is much more satisfactory than the wheeler and second only to the small scoop. A peculiar advantage of the Fresno for certain kinds of work is that it can be made to take a heavy or light cut at the option of the driver. In grading lawns, finishing cuts, etc., the Fresno can take a thin slice of an inch or a deep scoop of nearly a foot with equal facility, and is controllable in loading by one hand on the dumping lever.

$R = 900.\dfrac{2 + 2}{600 \times \frac{1}{3}} = 18$ ct. per cu. yd. for wheelers. $= 900.\dfrac{2 + 0.75}{600 \times \frac{1}{4}}$ $= 16\frac{1}{2}$ ct. per cu. yd. for Fresnos, showing the latter to be more economical.

Or suppose the assumptions are as in Table XI.

TABLE XI.

	Wheelers	Fresnos
D	440′	440′
S	220′ per min.	220′ per min.
KS	220′ per min.	220′ per min.
K	1	1
1/K	1	1
l (1½ + ½)	2 min. (½ + ¼)	0.75 min.
D/S (1 + 1/K)	4 min.	4 min.
W	600 min.	600 min.
w	⅛ cu. yd.	¼ cu. yd.
C	900 ct.	900 ct.

TABLE XII.—FRESNO SCRAPER COSTS (1914)

Material.	No. of scrapers.	D.	D′.	S.	KS.	K.	l.	Load, cu. yd.	Cost, cu. yd.	Transportation. Static cost per cu. yd. in ct.	Total.	Cost per cu. yd. in ct. per 100 ft. haul.
C. and L.	4	125	165	177	210	1.09	0.39	.240	11.7	2.4	9.3	7.4
S. and C.	3	125	190	188	205	1.09	0.48	.286	11.5	2.6	8.9	7.1
L.	3	100	200	226	236	1.04	0.43	.246	11.3	2.8	8.5	8.5
L.	3	155	155	265	226	0.85	0.44	.250	11.3	2.9	8.4	5.4
L.	3	200	300	226	218	0.97	0.53	.296	14.0	2.9	11.1	5.5
L.	3	130	120	226	234	1.03	0.51	.280	9.4	3.0	6.4	4.9
L.	3	85	105	193	216	1.12	0.51	.280	8.5	3.0	5.5	6.5
L.	2	120	145	264	199	0.75	0.42	.250	11.9	3.1	8.8	7.3
S. and C.	3	155	195	187	189	1.01	0.57	.286	13.5	3.2	10.3	6.6
L.	2	85	105	260	254	0.98	0.49	.280	8.2	3.3	4.9	5.8
C. and S.	3	135	180	198	222	1.12	0.61	.286	11.8	3.4	8.4	6.2
L.	3	112	135	187	238	1.27	0.47	.230	11.8	3.4	8.4	7.5
L.	2	120	140	200	208	1.04	0.54	.250	11.8	3.5	8.3	6.9
S. and C.	3	200	235	212	248	1.17	0.66	.286	13.8	3.6	10.2	5.1
L.	3	112	125	208	283	1.36	0.58	.250	10.3	3.8	6.5	5.8
S. and C.	3	260	310	196	228	1.16	0.64	.250	21.0	4.0	17.0	6.5
C. and S.	3	170	195	226	233	1.03	0.73	.286	13.0	4.1	8.9	5.2
L.	3	140	150	206	235	1.14	0.63	.230	12.7	4.1	8.6	6.1
S. and C.	3	175	210	211	256	1.21	0.78	.286	13.5	4.3	9.2	5.3
S. and C.	3	155	185	218	214	0.98	0.80	.286	13.2	4.4	8.8	5.7
C. and S.	3	130	155	185	208	1.12	0.80	.286	12.5	4.5	8.0	6.1
S. and C.	3	155	180	201	163	0.81	0.82	.286	14.9	4.5	10.4	6.7
L.	3	200	300	204	211	1.03	0.87	.278	18.8	5.0	13.8	6.9
S. and C.	3	245	270	220	212	0.96	1.06	.286	19.1	5.9	13.2	5.4
S. and C.	3	195	235	196	168	0.86	1.15	.286	19.7	6.4	13.3	6.8
S.	3	300	315	214	224	1.05	1.07	.250	24.6	6.8	17.8	5.9
L.	3	120	170	217	195	0.90	1.14	.250	16.7	7.4	9.3	7.7
Min.	2	85	105	177	163	0.75	0.39	0.230	8.2	2.4	4.9	4.9
Av.	3.0	156	192	212	220	1.05	0.67	0.269	13.7	4.0	9.7	6.3
Max.	4	300	315	265	283	1.36	1.15	0.296	24.6	7.4	17.8	8.5

Under "Material"—C. and L., clayey loam; S. and C., clayey sand; L., loam; S., sand. D—Loaded haul in feet. D′—Empty haul in feet. S—Loaded speed in ft. per min. KS—Empty speed in ft. per min. K—Ratio of empty and loaded speed. l—Time other than that of transportation, in min.

$$R = 900.\frac{4+2}{600 \times \frac{1}{2}} = 27 \text{ ct. per cu. yd. for wheelers} = 900.\frac{4+0.75}{600 \times \frac{1}{4}}$$
$= 28\frac{1}{2}$ ct. per cu. yd. for Fresnos.

Showing that now the wheelers are working the more economically.

Table XII gives results of a large number of cost data on Fresno work in various materials, arranged in the same manner as those on wheelers in the early part of this article.

Below are shown in detail time studies of various observations, with remarks upon the conditions affecting the results.

The observations in Table XIII show the Fresno to have been working very well. The material was a loam and clay, enough of the latter being present to form an ideal track for the scrapers, hard and smooth. The loads were of good size.

TABLE XIII.—FRESNO SCRAPER WORK IN CLAYEY LOAM

	Waiting and preparing to load Min.	Sec.	Loading Min.	Sec.	Transporting loaded Min.	Sec.	Transporting empty Min.	Sec.	Other delays Min.	Sec.
	0	03	0	7	0	53	0	50	0	3
	0	12	0	7	0	38	0	35	0	0
	0	25	0	8	0	32	0	40	0	0
	0	11	0	6	0	41	0	51	0	0
	0	9	0	8	0	29	0	41	0	0
	0	12	0	12	0	50	0	58	0	15
	0	10	0	8	0	55	0	47	0	0
	0	7	0	5	0	39	0	48	0	0
	0	13	0	15	0	45	0	46	0	7
	0	6	0	8	0	43	0	53	0	16
Av.	0	11	0	8½	0	42½	0	47	0	4

D	125′
D′	165′
S — 125′/42′ ½ s.	177′ per min.
KS — 165′ 47 s.	210′ per min.
K — 210/177	1.19
l	0 — 23½
D/S + D′/KS	1 — 29½
w	0.24 cu. yd.
C — 35.75/4	894 ct.
W	600 min.

4 scrapers and drivers at $7.20	$28.80
1 loader	1.95
1 foreman	4.00
1 waterboy	1.00
	$35.75

$$R = \frac{894}{600} \times \frac{1.88}{0.24} = 27.4 \text{ ct. per cu. yd.} = 2.4 \text{ ct. static} + 7.4 \text{ ct. per 100-ft. haul.}$$

The static cost here is considerably below the average, which shows at once that there was very little wasted time, and that the work moved smoothly. The transportation cost is somewhat above the average and a glance at *S* and *KS*, the rates of moving, which are low, makes the reason apparent, showing that as a whole the work went smoothly, but slowly. No doubt the general speed of this work could have been considerably increased and still have things move nicely. but it is preferable to have the

work run uniformly even at the expense of speed than to rush in transit and wait idle about the loading point.

The observations in Table XIV were made where the material handled was top-soil, rather sticky from recent rains.

TABLE XIV.—FRESNO SCRAPER WORK IN HEAVY TOPSOIL

	Waiting at loading point Min.	Sec.	Loading Min.	Sec.	Transporting loaded Min.	Sec.	Turning at dump Min.	Sec.	Transporting empty Min.	Sec.
	0	40	0	40	0	23	0	14	0	46
	0	37	0	14	0	32	0	14	0	50
	0	15	0	8	0	37	0	20	0	50
	0	50	0	9	0	36	0	25	0	50
	0	20	0	15	0	38	0	22	0	65
Av.	0	32.4	0	17.2	0	33.2	0	19	0	52.2

D ....120′
D′ ....170′
S — 120′/33.2 sec. .....217′ per min.
KS — 170′/52.2 ....195′ per min.
K — 195′/217 ....0.9
l ....1 min. 08.6 sec.
D/S + D′/KS ....1 min. 25.4 sec.
w ....0.25 cu. yd.
C— 2925/3 ....975 ct.
W ....600 min.

Cost of 3 scraper gang $29.25

$$R = \frac{975}{600} \times \frac{2.57}{0.25} = 16.7 \text{ ct. per cu. yd.} = 7.4 \text{ ct. per cu. yd. static} + 7.7 \text{ ct. per 100-ft. haul.}$$

In this instance the static cost is far above the average, due to excessive idle time. In the first place the time of "Waiting at Loading Point" is far too high and arose from a condition very often observed upon scraper work for the existence of which there is no excuse or reason except negligence upon the part of the man in charge. This is allowing the scrapers to get bunched together so that the work becomes spasmodic. Teams are idle at the loading point waiting for the ones ahead to be loaded and when all are en route to the dump the loader is idle until the first arrives again. In consequence the whole speed of action is reduced. It is just as easy to keep teams equally spaced, especially when there are but three or four upon a short haul, as in this case. Then the loader works with regularity, the teams move with uniform speed, do not get bunched, and there is no necessity of wasting time in idle waiting. In the second place the loading time is too great. This was due to the scrapers frequently hitting some hard spot not sufficiently plowed, overturning and having to turn about for reloading. Having the ground well plowed is of prime importance in Fresno work, as it cuts down the actual loading time, and keeps the whole work in motion better. In the third place the time "Turning at Dump" should be reduced one-half. There is no necessity of stopping a second in dumping

and once the scraper is empty the driver should turn his team right about without moving from his tracks. Too often a long sweep is made, wasting much valuable time. The transportation charge is above the average due to the slow return from the dump (*K* and *S*), arising also from crowding and the material reduction of speed occurring when drivers see that teams ahead of them are idle at the loading point.

In the work for which the time study, Table XV, was made the material was well plowed top soil in almost ideal condition for Fresno work.

TABLE XV.—FRESNO SCRAPER WORK IN WELL LOOSENED TOP SOIL

	Waiting at loading point Min.	Sec.	Loading Min.	Sec.	Transporting loaded Min.	Sec.	Dumping and turning Min.	Sec.	Transporting empty Min.	Sec.
	0	10	0	6	0	32	0	11	0	31
	0	15	0	6	0	34	0	8	0	32
	0	16	0	6	0	40	0	10	0	31
	0	15	0	7	0	33	0	9	0	33
	0	12	0	5	0	34	0	12	0	32
	0	15	0	5	0	27	0	13	0	33
	0	9	0	4	0	36	0	12	0	34
	0	13	0	5	0	30	0	15	0	25
	0	25	0	8	0	44	0	10	0	27
	0	8	0	7	0	36	0	10	0	30
Av.	0	13.8	0	5.9	0	34.6	0	11	0	30.8

D	130′
D′	120′
S	226′ per min.
KS	234′ per min.
K — 234/226	1.035
l	0 — 30.7 sec.
D/S + D′/KS	1 — 05.4 sec.
w	0.28 cu. yd.
C — 29.75/3	992 ct.
W	600 min.

Cost of 3 scraper gang $29.75

$$R = \frac{992}{600} \times \frac{1.6}{0.28} = 9.4 \text{ ct. per cu. yd.} = 3.0 \text{ ct. static} \times 4.9 \text{ ct. per 100-ft. haul.}$$

Here both static and transportation charges are below the average. A more uniform spacing of scrapers was observed with the result that the idle and loading times were materially reduced; and the rate of transportation was very satisfactory accounting for the low transportation charge.

To secure cost diagrams, Fig. 173, for Fresno scraper work, average values may be substituted in the general transportation formula given above, where: $C = 879$ ct.; $l = 0.67$ min.; $W = 600$ min.; $S = 212$ ft.; $K = 1.05$; $1/K = 0.95$, load and haul being variable.

The costs above given do not include anything for overhead charges, superintendence (above foreman), preparatory charges,

office expenses, contractor's profit, etc. This refers to both classes of scrapers. These values are plotted on the accompanying chart, from which with conditions approximately as assumed the cost of such work for various lengths of haul may be read directly.

When Fresno scrapers are loaded from plowed ground it is infinitely easier to load when dragging across than lengthwise of the furrow. Double plowing is often economical. The dumping operation should be accomplished by a quick, sharp lift on the han-

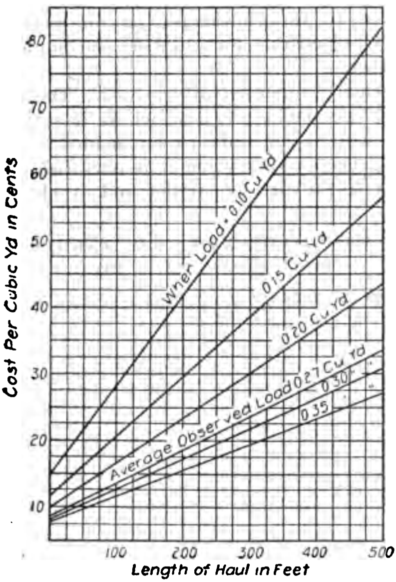


Fig. 173. Curves Showing Cost Per Cubic Yard of Handling Loam, Sand, etc., with Fresno Scrapers for Various Sizes of Load and Length of Haul. (1914 Prices.)

dle, and preferably on a down grade. When the ground is very well loosened the driver can do his own loading as well as dumping. The path to the dump must be reasonably free from obstructions, else the scrapers may dump themselves without intention on the driver's part.

General Hints on All Scraper Work. (1) Be sure to use the right kind of scraper. A Fresno with three mules is economical up to about 275 ft. of haul as against wheel scrapers with 2

mules, when it can load readily. Where the ground is full of roots use wheelers.

To drivers:

(2) Report any case of bad fitting harness to the foreman immediately. Don't let the team drag you by the reins. You are supposed to be able to walk as fast as a loaded team.

To foreman:

Make a personal detailed inspection of each mule's harness the first thing in the morning and at noon, and report any case of ill fitting harness to the timekeeper on his next round. Foremen will be held responsible for allowing any mule to work with badly fitting harness.

(3) See that each scraper is fully loaded. The cost of plowing is less than 1 ct. per cubic yard, which is less than the cost of letting scrapers work when only partly loaded.

(4) In loading the scraper when it is once full of earth do not let the mules try to pull it any farther and overload it. The last

DATA USED IN CALCULATING CURVES, FIG. 173, FOR FRESNO SCRAPERS IN LOAM, SAND, ETC.

Five scrapers in standard gang. Three animals per scraper.

Mules at \$1.75	\$26.25		
Drivers at \$1.95	9.75		
Loader at \$1.95	1.95	Per scraper C	8.79
I. D. R. at 3% per month	0.98	Value of scraper	\$13.75
Fireman at \$4.00	4.00	Value of harness	50.00
Waterboy at \$1.00	1.00		
Total (1914 figures)	\$43.93		

$$R = \frac{1}{w}\left[\frac{879 \times 1.95\,D}{212 \times 600} + \frac{879 \times 0.67}{600}\right] = \frac{1}{w}\left[0.0135\,D + 0.98\right] = \begin{cases} \frac{1}{w}(2.33) & \text{for } 100' \\ \frac{1}{w}(3.68) & \text{for } 200' \\ \frac{1}{w}(5.03) & \text{for } 300' \\ \frac{1}{w}(6.38) & \text{for } 400' \\ \frac{1}{w}(7.73) & \text{for } 500' \end{cases}$$

w.	D = 100'	200'	300'	400'	500'	
.10	23.3	36.8	50.3	63.8	77.3	For 5 scrapers
.15	15.5	24.5	33.5	42.5	51.5	
.20	11.6	18.4	25.1	31.9	38.6	
.27	8.6	13.6	18.6	23.6	28.6	
.30	7.8	12.3	16.8	21.3	25.8	
.35	6.7	10.5	14.4	18.2	22.1	

two seconds of drag against the dead weight of earth are mule killers.

(5) On all scraper work drivers are required to walk at all times when the scraper is loaded and they are to walk at all times with the Fresno scraper, whether loaded or empty. With wheeler scraper work drivers should ride on the scraper when it is empty. In stepping on or off of the scraper be sure not to delay the team in any way.

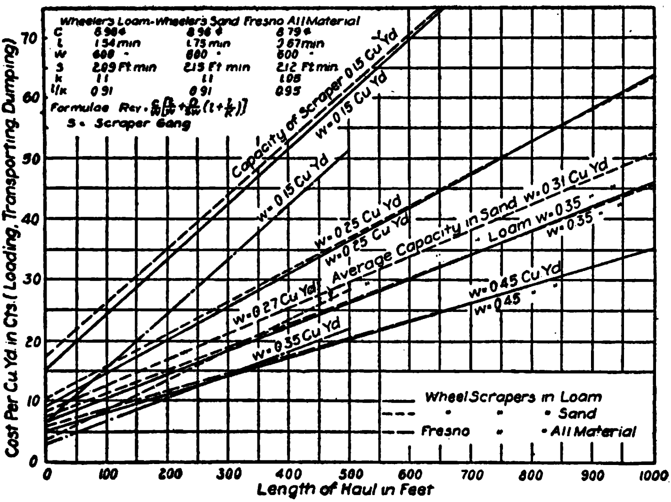


Fig. 174. Diagram Comparing Economy Up to 275 Ft. Haul of Fresno and Wheel Scrapers.

(6) In dumping wheel scrapers try not to dump when the mules are on ground that is lower than the scraper, as by doing this it brings a tremendous load on the mules' necks.

(7) So direct the work that the loaded teams will have the shortest haul and the empty teams if necessary may have a much longer haul, but in no case should the empty haul be unnecessarily long. It is better to let the mule team stand still to rest than to let it cover unnecessary ground. This seems like a simple rule, but its violation has often been observed on several different jobs.

(8) See that the scrapers are spaced as even a distance apart

as possible. This will make the work lighter on the mules, easier on the drivers and will tend to avoid confusion.

(9) The loaded scraper should always have the right of way as against the unloaded scraper.

(10) Whenever a scraper gets stuck or is in any trouble don't lose any time before notifying the foreman and sending for help. The snatch team is employed for the purpose of helping the scrapers at all times and in all possible ways.

(11) Be sure not to have too few scrapers on a long haul and too many scrapers on a short haul; see that every scraper is busy all the time; see that the loader and snatch teams are busy all the time; in short, that each unit of the work is contributing its maximum effort to the accomplishment of the whole.

Figure 174 is a diagram showing that Fresno scrapers are more economic than wheel scrapers up to 275 ft. haul.

Fig. 175. Doan Scraper.

Tongue Scrapers. This machine is composed of a wooden platform drawn at an angle of about 60° with the surface of the ground and the horses are hooked to the pole. It is a very valuable machine for filling ditches, leveling roads or other uneven places. The author has found it an extremely economical machine for spreading topsoil which had been previously stacked in piles. It has a steel cutting edge 48 inches wide, which can be easily replaced. The weight is 120 lb. and the price $10.00.

The Doan Scraper. This machine is very useful for cleaning out and back filling ditches or leveling uneven surfaces. Manufacturers claim that it will back fill as much earth as 50 men with shovels. Price, $9.20.

Graders and Road Machines. The difference between graders

and scrapers is that the scrapers pick up a load, transport it a certain distance and unload it at once place, while the road machine is used mainly for cutting off high places and filling up the adjacent low places while the machine is in motion. Another function of the grader is that of moving earth into winrows, or of spreading it from winrows in thin layers.

Fig. 176. Fresno Scraper.

Reversible Graders. A make of steel grader, the smallest of which can be operated by a man and two horses, and the largest by a traction engine, costs as follows:

Length of blade in ft.	Weight in lb.	Price f. o. b. Chicago
6	1,450	$ 250
7	2,600	400
7	2,900	475
8	2,900	450
7 or 8	3,100	525
10 or 12	7,100	1,375

Another make of graders costs as follows:

Length of blade in ft.	Weight in lb.	Price f. o. b. factory
6	1,600	$ 250
8	3,300	500
10	5,500	850
12	7,000	850

A machine that will rip up old macadam road and grade it at the same time has the following specifications: Number of rooter teeth 5, spacing, center to center 10 in., length of grader blade 9 ft., approximate weight 8,400 lb., price, f. o. b. Chicago $1500.

Two Blade Adjustable Road Drag. A drag similar to the one shown in Fig. 179 is used to cut, crush, pulverize, pack, smooth and carry earth. The various operations are accomplished by the

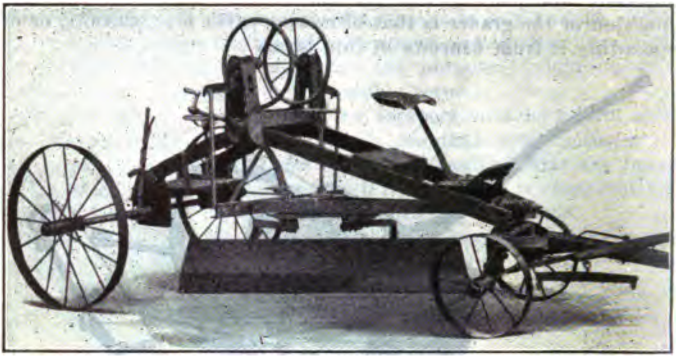


Fig. 177. Reversible Grader.

adjustment of the blades. This machine weighs 280 lb. and costs $33.00 f. o. b. factory. Another make of a similar drag weighs 300 lb. and costs $30.00 f. o. b. Chicago.

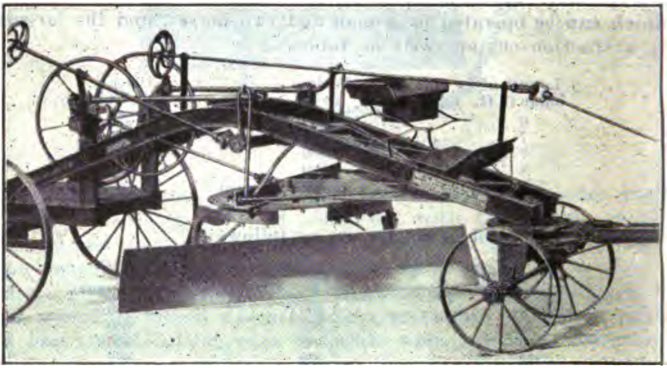


Fig. 178. Reversible Grader.

Three Blade Drag similar to the above, but designed for much heavier work weighs 380 lb. and costs $40. The length of the blades is 7 ft. 6 in., and the width 6 in.

Road Hone mounted on wheels similar to the one in Fig. 180 is used for smoothing puddling and leveling dirt roads. It weighs complete 365 lb. and costs $70. It is operated by one pair of

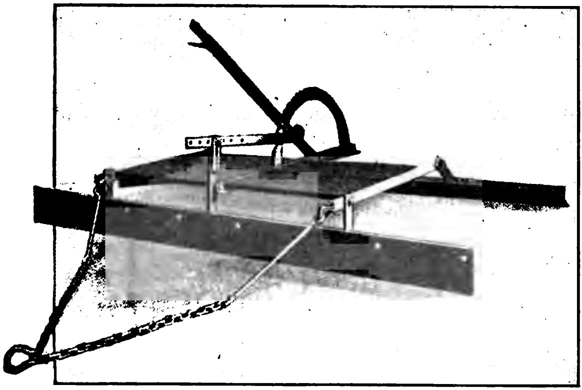


Fig. 179. Two-Blade Adjustable Road Drag.

horses and is moved on its own wheels without tearing up the road.

Three-Way Road Drag, Fig. 181, will cover the entire width of the road in one trip. A drag designed for horse power weighs 650 lb. and costs $80. Another make weighs approximately 1000

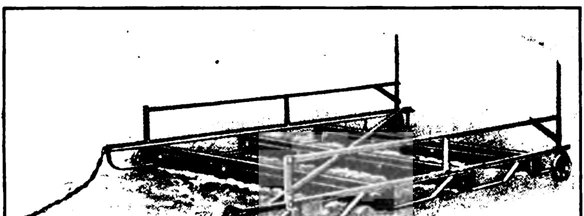


Fig. 180. Road Hone.

lb. and costs $92. A heavier drag for engine power weighs 1,250 lb. and costs $120.

Cost of Moving Dirt with Power Machinery. The following

notes appeared in *Engineering and Contracting*, May 15, 1918, and exemplify in a striking way that we are moving in the Epoch of Manufactured Power.

Using power machinery only, 125,000 cu. yd. of dirt were moved on an Illinois road job, at a cost of 4.1 ct. per cubic yard. The work was done in connection with the improvement of a road leading north toward Pontiac, Ill. The first 5 miles of this highway was changed from a narrow winding road to a level, well drained all the year road, 60 ft. wide between fences and 40 ft. wide between drainage ditches.

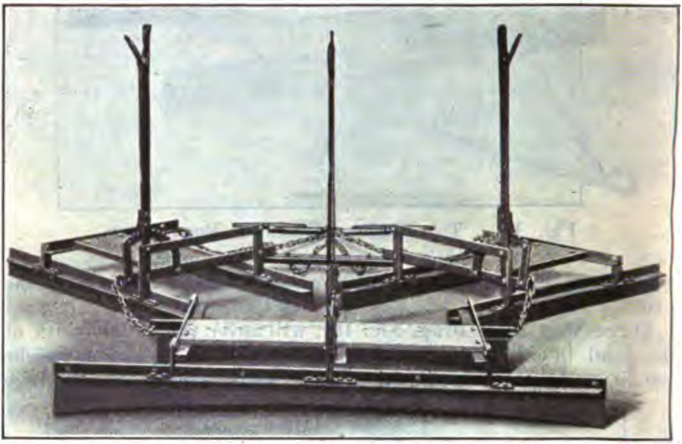


Fig. 181. Three-Way Road Drag.

The work of clearing the right-of-way was started on May 1, 1917, and completed June 16, 1917, during which period 5 18 acres were cleared of a tangled mass of brush and shrubs and over 200 live trees from 3 in. to 3 ft. in diameter. Trees were pulled by a 75-hp. caterpillar tractor using a 100-ft. cable. Two cable outfits were used, so that the tractor was not delayed waiting for hitches to be made. The cost of clearing the roadway, including labor, interest on investment and an allowance of 20% for depreciation of equipment, was $990.90, or $191 29 per acre.

The grading was started on June 18, 1917. One 75-hp. caterpillar tractor was used to pull two Western graders, one 12-ft. to make the cut, followed by an 8-ft. to carry the dirt to the center of the road. A Western elevating grader pulled by a

75-hp. caterpillar tractor was used in some places in making fills. However, on some of the deeper fills it was necessary to use some other method, in order to make time, and a 75-hp. caterpillar tractor was used in connection with a caterpillar land leveler. This land leveler is a tool used extensively in the West and is in reality a large scraper having a capacity of approximately 3½ yd. With this machine the dirt could be taken up and carried across the road and then unloaded gradually or all at one time as conditions required.

The gravel for the road was taken from a nearby creek with a drag line excavator which delivered it to a loading hopper. With the drag line excavator working steadily it was possible to keep the hopper filled, so that when the tractor train came up, which consisted of a 75-hp. caterpillar tractor with 6 reversible trailers, they could be loaded without delay or without shoveling.

With this equipment a total of a little over 125,000 cu. yd. of dirt was moved in 75 working days. The total cost including labor, interest on the investment and an allowance of 20% on depreciation of equipment was $5,147 or 4.1 ct. per cu. yd.

At no time were more than 8 men employed on the job. Horses or mules were not used at any time in the work.

A Gravel Spreader was used in the construction of the Colorado River Levee. This spreader was built on an ordinary flat car and is of extremely simple construction. A small, well-braced tower is built in the center and on each side 8 x 17 in. pine stringers are firmly bolted to the side sills and to stringers laid across the top of the car body. Ten 1¼-in. eyebolts run up through these stringers and from these are suspended two isosceles triangular wings, one on each side of the car. These wings are raised and lowered by means of ropes and blocks at the point of the wings and at the top of the tower and are raised by braking the car and hauling on the line by a locomotive. On the outside the wings are faced with iron and have a reach of 15 feet. The 45-yard side-dump cars were unloaded when standing still, so that the top of the dumps on either side was from 3 to 4 feet above the tracks. In spreading this material the machine is put through the entire length at a speed from 7 to 10 miles per hour. Several trips with the wings at different heights are sometimes necessary. The cost of spreading material per yard is about 1/10 cent, the cost of constructing machine about $300.00, and its operation requires the service of a locomotive and of four men to handle the wings. This work was prior to 1912.

Grading for Roads Across Sloughs by Bull-Dosing. The following notes by Mr. L. U. Martin appeared in *Engineering and*

Contracting, May 7, 1919. This method is particularly adapted to sloughs containing standing water and to short stretches of bog. The grade for this work should be carried from 40 to 60 ft. wide at the base; or in the case of standing water to a minimum width of 40 to 45 ft. at the water level. Wagons or scrapers are dumped as close to the edge as it is possible to drive the teams and the dirt is then pushed ahead by the bulldoser. A good operator on the bulldoser can handle the dirt from 5 to 6 teams on an average haul of 500 ft., and more as the length of haul increases. With a good operator little time is lost over a straight haul on good ground. The outfit shown was pushing for five No. 2 wheelers (15 cu. ft.) on a 400-ft. haul. A heavy steady team is required to handle this pusher. The actual cost per yard over straight haul dirt with a good operator should not exceed

Fig. 182. Pushing the Grade with a Bulldoser.

2 ct. per yard, and may even run below this Unless dirt can be sent both ways from the cut, however, or the fill is long enough to use the full outfit, an elevating grader is not worked at full capacity and the extra cost per yard on this account will be raised to perhaps 6 ct additional as a maximum.

The outfit was a home-made affair consisting of the front wheels of a dump wagon, a straight telephone pole 8 in. at the butt and 20 ft. long, and a push board braced as shown, shod with a 3-in. by ⅛-in. iron edge on the bottom. It was so made that the pole with board attached could be removed in a few minutes from the wheels and loaded on a wagon. This method is much superior and cheaper than the old one of having shovelers at the end of the grade pushing the dirt off with a shovel.

Jordan Spreader. On the Hudson Division of the New York Central & Hudson River R. R.. where considerable double tracking work was in progress, the Walsh-Kahl Construction Company

were using a dump car train and Jordan spreaders (Fig. 183) to widen out shoulders sufficiently to lay a construction track so as to clear the present main line tracks. With a good locomotive and crew a train load of 150 to 200 cu. yd. of ordinary material can be leveled so as to clear passing trains in 8 minutes and can be leveled down to 2 ft. below top of rail in from 10 to 15 minutes.

Fig. 183. Jordan Spreader in Use on Four Tracking.

The cost per day of a spreader may be estimated as follows, assuming all items liberally to insure their covering the cost in any case:

Depreciation on $5,000 machine at 15 years life, 250 days per year	$1.33
Interest at 5%	1.00
Repairs at $50 per year	.20
Labor, 1 operator	2.50
Oil, waste, etc.	.10
Total (1912 figures)	$5.13

This does not include cost of locomotive and crew.

This will indicate what may be the cost of using a spreader. If the machine is taken care of it should be sold at the end of 15 years for a reasonable price, but no account is taken of the scrap value in this estimate.

The machine can easily handle all material which can be supplied by trains which might be anywhere from 1,000 to 20,000 yards per day.

Spreader Plow. A new type of spreader plow built by the Bucyrus Co., is illustrated by Fig. 184. It weighs about 68 tons having a larger wing area and wider spread than any other plow. The width of spread may be varied automatically with

no loss of time and the wings may be opened or closed irrespective of their inclination. This plow will operate effectively with an ordinary train pressure of 70 lb of air and will operate with as low a pressure as 50 lb. The control is entirely automatic, one man being required for the operation.

The maximum width of spread from the center of the track is 22 ft 6 inches, 24 inches below the top of rail and 23 ft. 5 inches on level with the top of rail. Any intermediate width of spread may be obtained. The vertical travel of the wing is 43 inches, from 19 inches above to 24 inches below the top of the rail.

The car body is heavily built, trucks being M. C. B. Standard for 100,000 lb. capacity cars. Each main wing is made up of three heavy steel castings so designed that should the plow

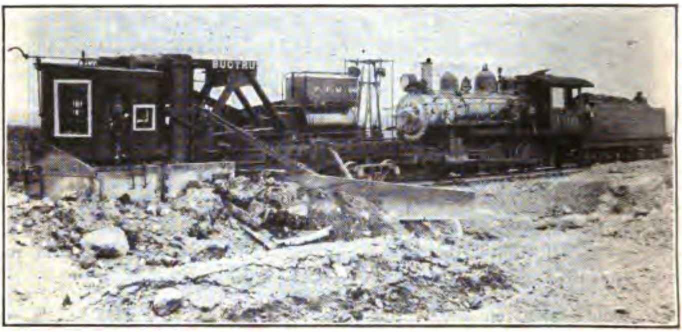


Fig. 184. Spreader Plow.

encounter an immovable object, the pins would shear, allowing the wings to swing without any damage to them.

The operating mechanism is entirely pneumatic, independent air cylinders being provided for each wing.

The operator's station is located forward where he can obtain a clear view of the work at all times, all controls being placed in the cab.

This machine is used for such work as spreading ballast, second tracking, grade revision, track elevation, bank building, bank trimming, ditching, spreading spoil dumps, snow plowing and yard construction.

The cost of operation consists of the pay of a single operator of about $5.00 per day, the cost of running the engine and a charge of about $5.00 per day for renewals and incidental expenses, plus, of course, interest and depreciation on the machine itself.

A plow of this type was used in embankment construction on the dumps of the Hull-Rust Mine at Hibbing, Minn. The material handled was mainly gravel with a sprinkling of boulders. The speed maintained in plowing usually averaged from 7 to 10 miles per hour.

The method of building the embankment was described in *The Excavating Engineer*, July, 1920, from which the following notes are taken.

A fairly level stretch was selected and the track laid in sections, with the joints broken evenly, in order to facilitate handling. These sections were unloaded from a flat car with a locomotive crane which spotted the sections ahead, these sections being bolted up as fast as laid. This track was made as level as possible by blocking up temporarily. The first procedure varied somewhat with the character of material encountered. Where this material contained considerable boulders, the load from the first dump was spread level with the top of the rail, thus building a 24-in. embankment. The tracks were then shifted to the top of this newly constructed road bed. It can readily be seen that with the most careful blocking the track contained considerable depressions. The facility with which the above mentioned embankment was made level, was accomplished by raising and lowering the wing as the material was spread, thus assuring an even grade.

When the material ran even and no large boulders were encountered, the first procedure was to plow 12 in. below the bottom of the tie, attaining this depth in successive cuts. This provided space in which to dump material, thus eliminating the tendency of the material to flow back on the rails when dumped from the cars.

When this 24-in. embankment was completed, material was dumped to the far side in order to anchor the track. This prevented the shifting of the track, due to the side thrust of the plow during later operations. This material was usually spread off level with the ties. The next procedure was to dump trains of 20-yard cars from the new track. This was done where the cars stood without spotting as it proved to be unnecessary to make one continuous pile and to butt the contents of one car against that of another. This not only facilitated plowing, but saved considerable time.

This dumping of material was spread in three steps with the wing horizontal, on the level with the track, fixed at a minimum angle of 12 ft. from the center of the track. The second step was to plow the same material with the wing fixed at 16 ft. width of spread, and then at the maximum or 22½ feet width of spread. These operations were repeated

three times, making a total of nine operations on this dumping. The same steps were taken each time except that the maximum width was reduced each time to two ft. or to 20½, 18 and 16 ft. respectively, each time gradually lowering the wing horizontally until the maximum depth had been reached or 2 ft. below the top of the rail. The purpose of decreasing the width each time was to raise the material higher and to lessen the side thrust on the rail and the power required to push the plow, and furthermore, to attain the object of throwing the material beyond the reach of the wing. The object of feeding down was, as stated before, to provide dumping area.

The base of the material was now 16 ft. from the center of the track. The wing was then raised horizontally to 19 in. above the top of the rail and the same dumping was plowed at the maximum width of 22½ ft. The purpose of this procedure was to carry the ridge over as far as possible and to build a shoulder at this width. It will be seen that this one dumping was plowed ten times.

Then more material was dumped in the space provided and this was plowed with the wing horizontal. This is repeated until a maximum depth of 24 in. and a 12-ft. width was attained.

The wing was then raised to the maximum of 19 in. above the track level and the material was thrown over as described before.

At this juncture, a bank had been constructed 5½ ft. in height, above the top of the rail.

The tip of the wing was then raised to the maximum of 7 ft. above the inner end. This consumed about 15 minutes. More material was then dumped and plowed. The plowing was first done with the wing at this inclination at a minimum width of spread. This width of spread was increased in three steps or to 12, 16, and 22½ ft., gradually lowering the wing each time, down to the maximum depth, maintaining the same angle of inclination.

This was repeated as often as necessary or until the material lay in a line from the inner point of the wing, 2 ft. below the top of the rail, to the tip of the wing at 22½ ft. from the center of the track. This again provided dumping space for a new load which was then dumped.

The wing was then raised, maintaining the same inclination, until its inner end was level with the top of the track. The material was plowed as before in steps of 12, 16 and 22½ ft., feeding down each time, (with the wing at the minimum width of spread), as before described, in order to provide dumping space for the next load.

More material was now dumped and the same procedure was

repeated each time changing the slope of the bank by bringing in the tip of the wing 1 ft. This added successive wedge-shaped slices to the embankment. This procedure was repeated until the minimum width of spread was reached, or 12 ft.

The embankment by this time had attained a height of 7 ft. with a top width of 10½ ft., this last dimension being the difference between maximum and minimum width of spread with the wing at the maximum inclination.

If it is desired to raise this embankment to a still higher elevation, the tracks may be lifted by a locomotive crane, section by section, and placed on this new embankment, and the above procedure repeated as often as necessary, as shown in the accompanying sketch.

It must be remembered that the procedure here described is that followed on the spoil dump of the Hull-Rust Mine at Hibbing, Minn., but it may readily be seen that conditions encountered elsewhere might alter the method employed in small details. For instance, if boulders were not encountered, the whole procedure would be considerably simplified. It was found that large boulders could be easily plowed and elevated if the wing encountered this boulder below its center.

Shrinkage of Earth Embankments when made with various kinds of equipment. Specific instances of shrinkage of railway embankments were cited in a committee report submitted at the 20th (1919) annual convention of the American Railway Engineering Association. Information was given regarding 8 embankments between mileposts 540 and 553 on the Atchison, Topeka & Santa Fe Ry. The following tabulation compiled from the report shows the percentage of material required to restore the several embankments to their original width after a lapse of 4 years' time:

	Quantities in fill at completion, Nov., 1911 Cu. yd.	Quantities required to restore fill to original width of 18 ft., Nov., 1915 Cu. yd.	Amount of shrinkage Per cent.
Embankment No. 1	15,762	1,824	11.6
Embankment No. 2	147,582	6,995	4.7
Embankment No. 3	125,680	2,371	1.9
Embankment No. 4	19 067	99	.5
Embankment No. 5	150,852	664	.4
Embankment No. 6	57,709	1,642	2.8
Embankment No. 7	33,902	1,678	5.0
Embankment No. 8	62,207	3,090	5.0

The base of embankment No. 1 was constructed from side-borrow with fresnos. It was topped with wheelers and carts. The material was brown pack sand, gyp and joint clay. The

base of embankment No. 2 was also made from side borrow with fresnos and wheelers. It was topped with cars. The material was the same as for No. 1. For No. 3 the base was placed with fresnos; it was topped with wheelers. The material was brown pack sand, gyp and joint clay. Several rains occurred during the period this fill was being placed which accounts for the small amount of shrinkage. The base of No. 4 was placed with fresnos; it was topped with wheelers using gyp and pack sand. The base of No. 5 was placed with fresnos from side borrow; it was topped with machine and wagons. The material was red sandy clay and gyp. Fresnos were used in placing the base of No. 6; it was topped with wheelers. The material was brown sandy clay and gyp. During the time this fill was being put in there were several very heavy rains, which accounts for small amount of shrinkage. The fill for embankment No. 7 was made from side borrow with fresnos; the material was black sandy loam and clay. The fill for No. 8 was made from side borrow, the base being placed with fresnos and the top with wheelers. The material was black sandy loam and brown sandy clay and gyp.

SECTION 45

HEATERS

A heater consisting of a steel framework (Fig. 185) the sides of which are built up of perforated shelves arranged so that the gravel or stone drops from one shelf to another and is heated by

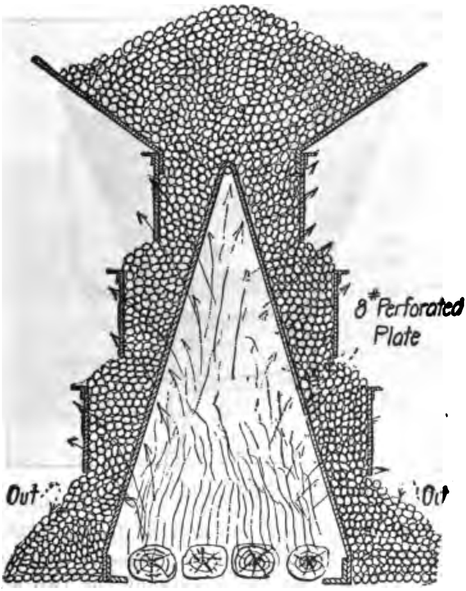


Fig. 185. A Portable Gravel Heater.

a fire built beneath. It will dry gravel or stone up to 2 in. in size, but cannot be used for drying sand.

No.	Cost	Capacity Tons per hour	Weight Lb.
1	$475	6	1,600
2	425	5	1,240
3	400	4	1,035
4	375	3	775

Heaters similar to the one shown by Fig. 186 suitable for drying sand are made in three sizes, with and without external gratings. They cost as follows:

Capacity in tons daily	Approximate shipping weight in lb.	Price f. o. b. factory
3½	550	$50
5	675	55
10	1235	90
	without gratings	
3½	450	$40
5	550	45
10	1050	75

Fig. 186. Sand Drying Stove.

Portable Sand Drier consisting of two drums, one within another, the inside one being 30 in. in diameter and 10 ft. long, and the outer 48 inches by 11 feet, giving the two a total area of 216 sq. ft. of heating surface, is operated by an 8 hp. engine with a 12 hp. boiler. The time required for the material to pass through the drums is stated to be four minutes. The capacity per hr. is 6½ cu. yd. of sand containing not more than 2% moisture heated to about 350° F. The heating is done by a kerosene or crude oil burner placed so as to fire the inner drum. The approximate fuel consumption is 75 gal. per day. This machine is mounted on a steel frame and wheels; it weighs approximately 7,500 lb. and costs about $1,800 f. o. b. Chicago.

A combination sand, stone and water heater is herewith illustrated (Fig. 188). It was used to heat the materials used in constructing concrete culverts on the New York Central & Hudson River R. R. It consists of a semi-cylindrical sheet of steel 10 ft. long and 2 ft. high. One end of the arch is closed and a short smokestack is erected on top. On the other end a water tank having a capacity of 97 gallons and with a radiation of 12 square feet is constructed. A wood fire is built under the

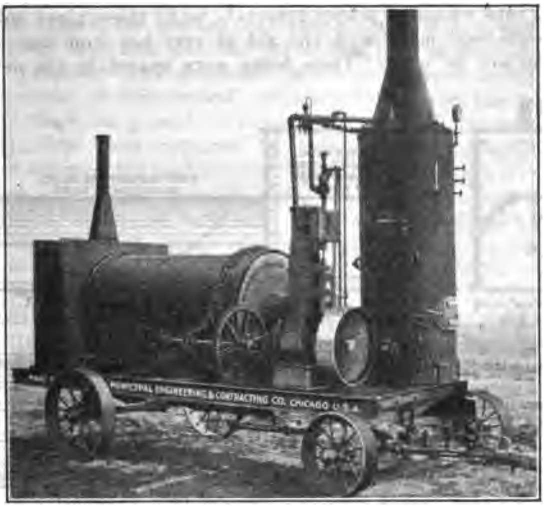


Fig. 187. Portable Sand Drier.

work and the sand and gravel to be heated are heaped on the top and sides. It weighs 1.200 lb. and can be built for about $100.

Rig for Thawing Frozen Ground. The following is from a report by the author, on a method of thawing frozen ground, during the winter of 1917–18, at the New York Navy Yard, while he was there in the capacity of Supervising Engineer. This method proved at least twice as efficient as any other previously known to him or to the contractor on that work.

In order to expedite the construction of the aircraft storage building at 35th Street, it was necessary to devise an effective method of thawing the ground within the building which had been frozen to an average depth of some 24 inches as a result

of the exceedingly cold weather that commenced in the last week of December, 1917.

As soon as the building was roofed and the sash glazed the contractor's expert devised a method that was substantially as follows:

A considerable number of ¾-inch steam pipes, each one connected with a valve and fitted with an elbow, were connected to a 25 hp. boiler through a 2-inch main in such a manner that a steam jet from each of these pipes could be directed into the ground into which at proper intervals to fit these pipes holes had been previously made with the aid of very hot iron bars worked into the soil by hand. These holes were spaced in the neighbor-

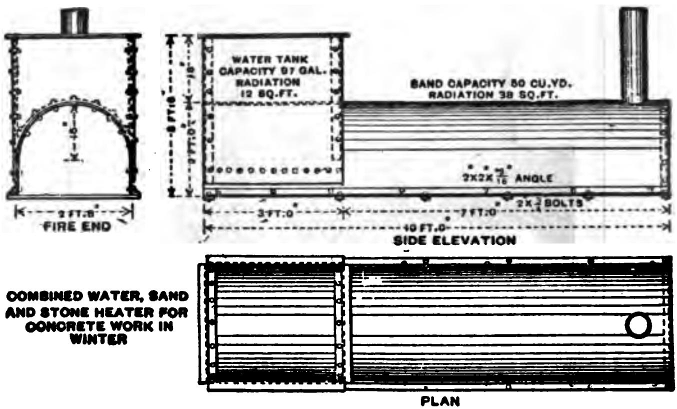


Fig. 188. Combined Water, Sand and Stone Heater for Concrete Work in Winter.

hood of three feet apart and after the pipes had reached to the bottoms of the holes previously driven, the entire affair, which measured some 20 feet x 50 feet, was covered with a tarpaulin stretched about 3 feet above the ground with enclosed ends and sides. Upon steam being turned on, the condensation resulted in each of the holes being filled with water which was kept at the boiling point by the issuing steam, and the hot water gradually thawed the ground and percolated into the ground between the holes, finally producing a boggy mass which had the merit of not being frozen. It had the disadvantage, however, of being so wet as to be unsuitable for the laying of concrete floor, and the method had the further disadvantage that it required about 48

hours to thaw out the ground, several hours to adjust the apparatus and several hours more for the water to drain away sufficiently to enable concreting to proceed. The method was very costly to the contractor and resulted in filling the building with moisture from the steam that escaped through and under the tarpaulins.

After some six days of experiment with the above described arrangement the contractor was induced to make a test according to a plan recommended by the author. The test having been very satisfactory, the method was adopted and is here described. The cost for labor and material per square foot of ground by the method proposed and described below is approximately one-third the cost of the method described above, and the time required to thaw the ground by the method to be described is about one-fourth the time required by the previous method. It is therefore believed the method has sufficient merit to deserve consideration. It is not claimed that the method is new and it certainly introduces no facts new to steam engineering or thermo-dynamics, and it seems rather surprising that it does not appear to be generally known to contractors who have occasion to lay concrete where the ground is frozen.

Few situations are more agonizingly baffling than to have to lay concrete on ground which one does not know how to thaw out rapidly, and it is believed that any method which may relieve such a situation at any time, no matter how simple or how crude, is deserving of being brought to the attention of those who have such work to do.

The method proposed and adopted is as follows: Six units of area for thawing were arranged, each unit consisting of 13 lengths of ¾-inch pipe 20 feet long. Each of the six units or coils has at its supply end one 2-inch x ¾-inch reducer and one ¾-inch globe valve, and at its return end one ¾ inch globe valve and the pipes are arranged as illustrated in the accompanying figure. By arranging the pipes in the manner shown, it is not necessary to connect and thread the pipes to the exact 20 ft. lengths, but they can be purchased as they come in the market, usually an inch or two overlength. A couple of pieces of 2 x 4-in. studding 18 feet long underneath each unit or coil is useful for moving the unit about from one completely thawed piece of ground to the next section to be thawed. It will be observed that in this manner steam is admitted to a unit of ¾-inch pipe amounting to some 260 feet in length and containing some 72 square feet of external heating surface. These units arranged six at a time, are laid directly on the frozen ground and covered by the tarpaulin, which is separated from the pipe

by 2 or 3 inches, accomplished by laying 2 x 4 pieces of wood upon the pipe at 3 or 4 foot intervals. The second tarpaulin is placed over the first and separated from it by the space of 3 or 4 inches in a similar manner.

6. A test was made on January 18, 1918, on an area of 2,000 square feet and the following figures obtained:

Area covered	2,000 sq. ft.
Depth of frost	15 inches
Outdoor temperature (average)	27 deg. F.
Indoor temperature (average)	33 deg. F.
Type of boiler	70 hp. locomotive
Average steam pressure	90 lb.
Radiation:	
2″ supply piping:	
Outdoor 30 feet	20 sq. ft. surface
Indoors 110 feet exposed to air	75 sq. ft. surface
¾″ heating coils:	
1,721 feet, covered with tarpaulins	451 sq. ft. surface

An efficiency test was run from 10:00 P. M. to 8:30 A. M., or 10.5 hours. The results obtained were as follows:

Coal used:	17.5 cu. ft.
or approximately	0.4 ton
Water used	815 gal.
Temperature (average)	35 deg. F.
Condensate	680 gal.
Temperature (average)	205 deg. F.
Uncondensed steam	16.5%

The cost of thawing out the ground was as follows:

Equipment cost:	
Transportation (both ways) and erection, 2 boilers	$135.00
Pipe and fittings, $531 less 50% salvage	265.50
Canvas covers, $500 less 75% salvage	125.00
	$525.50
Area of buildings (380′x 300′), 114,000 sq. ft.	$ 0.0046
Cost per Square Foot.	
Operating cost:	
Labor (engineers, tending coils and moving apparatus).	$735.00
Boiler rent	61.50
Coal	98.00
Total	$894.50
Area thawed 23,000 sq. ft.	
Cost per square foot	$ 0.0389
Total cost per square foot (1918 figures)	$ 0.0435

7. During the thawing process a trial was made of covering the steam pipes with sand and placing the canvas covers as before.

This method, however, did not give as good results as when no sand was used and was therefore discarded.

SECTION 46

HOISTING ENGINES

Steam driven engines are manufactured in an immense variety of styles. Below are given the average prices of the types most generally used. These prices and weights vary greatly, but they are accurate enough to be used for estimating. For the purpose of tabulating, hoisting engines have been arbitrarily divided into the following classes:

Double Cylinder Single Friction Drum Engine adapted to work in bridge building, pile driving, log skidding and general hoisting.

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
6	4,600	$1,360
10	6,700	1,500
16	8,500	1,950
20	9,500	2,125

Double Cylinder Double Friction Drum Engine. Adapted to hauling cars, pile driving, bridge building, operating derricks and general hoisting purposes, circular saws, concrete mixers, centrifugal pumps, etc.

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
6	6,050	$1,600
10	7,500	1,725
16	10,300	2,200
20	13,200	2,425

Double Cylinder Three Friction Drum Engine for boom derricks with orange peel and clam shell buckets.

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
12	11,300	$2,375
16	12,300	2,600
20	15,700	2,850
30	18,500	3,350

Double Cylinder Double Friction Drum Engine with reversing gears and drums for swinging boom derricks.

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
8	8 700	$2,250
12	11,000	2,525
16	12,500	2,750
20	13,900	3,125

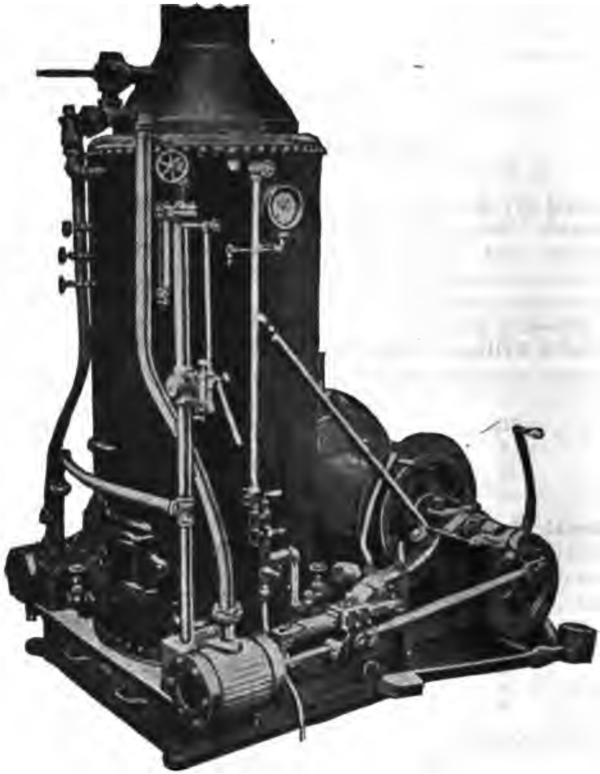


Fig. 189. Double Cylinder Single Friction Drum Engine.

Electric Hoists

Single Friction Drum Electric Hoist

Hp.	Approximate shipping weight in lb.	Price d. c. motor	Price a. c. motor
6	3,200	$1,090	$1,050
10	5,000	1,250	1,150
15	6,500	1,475	1,425
20	8,000	1,700	1,525

Double Friction Drum Electric Hoist

6	5,000	1,300	1,150
10	6,200	1,375	1,300
15	9,000	1,700	1,650
20	10,500	2,000	1,850

Fig. 190. Double Cylinder Double Friction Drum Engine.

Double Friction Drum Electric Hoist
with patent reversing boom, swinging gear and drums

12	8,500	2,100	2,000
16	9,500	2,400	2,150
20	11,000	2,600	2,450
25	12,500	2,900	2,650

Double Cylinder Double Friction Drum link engine with ratchets, pawls and winch for general hoisting and operating material elevator and elevator sheaves, etc.

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
8	7,500	$2,100
12	9,200	2,300
20	11,450	2,750

The prices for the foregoing hoisting engines are for the complete outfit. If the hoisting engine is to be used in connection

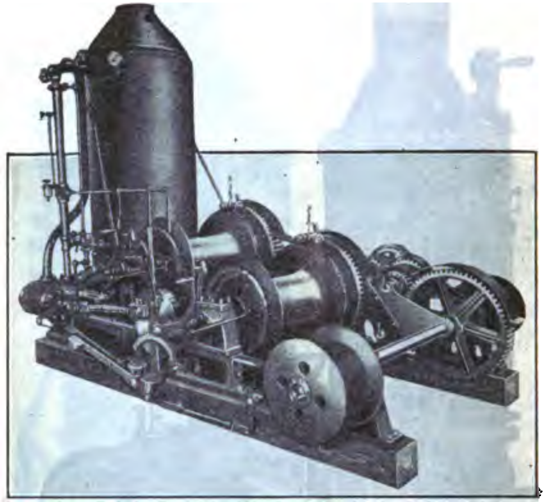


Fig. 191. Hoisting Engine with Boom Swinging Drum

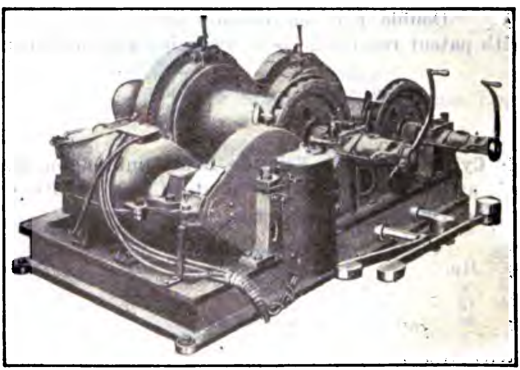


Fig. 192. Double Friction Drum Electric Hoist.

with a separate boiler plant the following approximate amounts should be subtracted.

Hp.	Amount to be subtracted to give price to engine without boiler
6	$570
8	600
10	600
12	750
16	850
20	925

Dredge Engines. A double cylinder, double friction drum dredge engine with brake bands and boiler costs as follows:

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
20	15,500	$3,400
30	19,500	4,300
50	26,000	5,700

Method of Computing Rope Capacity of a Drum. The method of computing rope capacity of a drum used by the A. Leschen & Sons Rope Company is as follows: Add the depth of flange in inches to the diameter of the drum, and multiply this result by the width (out to out) of the drum. This product is then multiplied by the figure below corresponding to the size of rope used:

¼ in.	4.16	1⅜ in.	.138
⅜ in.	1.86	1½ in.	.116
7/16 in.	1.37	1⅝ in.	.099
½ in.	1.05	1¾ in.	.085
9/16 in.	.828	1⅞ in.	.074
⅝ in.	.672	2 in.	.066
¾ in.	.465	2⅛ in.	.058
⅞ in.	.342	2¼ in.	.052
1 in.	.262	2⅜ in.	.046
1⅛ in.	.207	2½ in.	.042
1¼ in.	.167		

Cost of Operating Steam and Electric Motor Hoist. The following notes on an electric hoist as compared with a steam hoist appeared in *Engineering and Contracting*, Jan. 21, 1914.

The electric hoist does not require a licensed engineer. Almost any intelligent workman can learn to operate it. The control is very simple, and the motor requires no attention when operating. A single handle controls all motor operations. Throwing it one way starts the hoist in one direction, the speed depending upon how far the handle is moved; throwing the handle in the opposite direction reverses the hoist, the same speed range being also available.

The electric hoist requires no fireman, no fuel or water. There are no ashes to handle, no objectionable smoke and exhaust,

and no sparks, which eliminates the fire risk. The electric hoist is also lighter and more compact than the steam hoist with its boiler, and is therefore cheaper to move.

Where the steam hoist is driven from an independent boiler, steam pipes, which are leaky and awkward to handle, must be laid. The electric hoist, on the other hand, gets its power from flexible cables which can be run anywhere with ease.

Another advantage of the electric hoist is that it consumes power only when actually in use, and when at rest involves no expense for power whatever, whereas with a steam hoist, steam must be kept up, and frequently the stand-by expense exceeds the actual operating expense.

The motor-driven hoist is in general less likely to be out of commission than a steam hoist. It can be started at any time without delays for steaming up. There is nothing about it to freeze up and hence it is independent of weather conditions. The simple construction of the motor, with its two bearings only and no reciprocating parts, insures minimum delays for repairs, and as for reliability, motors designed especially for crane service are as strong and rugged as any steam engine.

There remains nothing but a consideration of the cost for current as compared with that for coal. This will naturally vary with local conditions, but it can be stated that in general the cost of operating an electric hoist will not be greater, all factors considered, than that of operating a steam hoist.

For example, with a coal hoist in Pittsburgh, where a motor was directly substituted for a steam engine, all other factors remaining the same, the following results were obtained:

Cost of coal per month	$ 60	
Cost of water per month	15	
Cost of electric power per month		$ 77
Wages of engineer per month	125	
Wages of motor operator		75
Totals	$200	$152

Thus the electric hoist showed a saving of $48 per month. But it also proved itself able to handle more coal. With the steam hoist, a bucket containing 42 bushels was lifted every 60 seconds, whereas the electric hoist required only 50 seconds for the trip, because it could be accelerated more rapidly. Hence in a 10-hour day the electric hoist can perform 120 more trips, or handle over 5,000 bushels more than the steam hoist.

The cost in labor of unloading from cars and setting up a hoisting engine ready for work averages from $35 to $50 (1910 prices).

Gasoline Hoist. The following are some prices of gasoline

driven hoists. These are furnished complete with magneto equipment. If battery reserve is also required the price is $10 extra.

CHAIN DRIVEN SINGLE DRUM HOISTS

Back geared — non reversible

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
6	2,860	$675
9	3,580	800
13	4,680	950

CHAIN DRIVEN DOUBLE DRUM HOISTS

Back geared — non reversible

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
6	3,580	$ 890
9	4,400	1,015
13	5,400	1,165

Fig. 193. Gasoline Hoist.

A small chain driven gasoline hoist, portable, non-reversible having a single drum, horse power $3\frac{1}{2}$; approximate shipping weight 1,850 lb. is priced at $445 f. o. b. factory. A similar machine of the same horse power with a double drum weighs about 2,200 lb. for shipment and is priced at $625.

Gasoline hoists of another make are priced as follows:

Heavy Duty Double Drum Hoists

(non-reversible, with magneto and friction clutch)

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
none	2,250	$ 730
8	3,400	1,075
10	4,050	1,120
15	4,400	1,550
	reversible	
none	2,350	$ 835
8	3,500	1,180
10	4,150	1,300
15	4,500	1,600

Double boom swinger for the above, complete, $200. If friction clutch gear is not wanted deduct $46. If Bosch magneto is not wanted deduct $60.

Heavy Duty Single Drum Hoists

(non-reversible, no magneto or friction clutch)

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
none	1,350	$ 380
6	2,215	655
8	2,340	725
10	3,135	840
15	3,250	1,150
	reversible	
none	1,450	$ 483
6	2,315	760
8	2,440	830
10	3,235	945
15	3,350	1,250

In the above hoists the drums hold 1.250 ft. of ½-in. cable, and have a line speed of 150 ft. per min. If an independent winch head is wanted add $57 to the above prices.

These machines may also be had in a light duty type having a drum capacity of 750 ft. of ½-in. line and a line speed of 125 ft. per min. The non-reversible double drum type may be had in three sizes 4½, 6 and 8 hp. It weighs 1,250 lb. without engine, 1,850 to 2,490 lb. for shipment with the engine. The price is $455 without engine and from $655 to $800 with engine.

The reversible light duty double drum type weighs about 100 lb. more, and costs $50 more for each size.

The light duty single drum non-reversible hoists weigh 800 lb. and cost $250 without engine. With a 4 hp. engine it weighs about 1,450 lb. for shipment and costs $455. The 6 hp. size weighs about 1,650 lb. for shipment and costs $530.

The light duty reversible single drum hoists weigh about 100 lb. more and cost $55 more than the non-reversible type.

Extras for the light duty hoists cost as follows:

Double boom swinger, complete	$200
Independent winchhead, complete	57
Bosch magneto	55
Friction clutch engine gear	45

Light single drum hoists having a drum capacity of 750 ft. of ½-in. cable, a line speed of 100 ft. per min. and a single line pull of from 750 to 1,350 lb. cost for the non-reversible type as follows:

Hp.	Approximate shipping weight in lb.	Price f. o. b. factory
none	450	$ 80
3½	975	242
4½	1,065	282
6	1,375	357

The reversible light single drum hoists weigh about 100 lb. more and cost about $70 more than the non-reversible for each size. Magneto $55 extra.

Fig. 194. Reversible Belt Driven Hoist.

Small Belt Driven Hoist. A reversible friction hoist designed to be operated by a gasoline engine or motor through a belt has the following specifications:

DIMENSIONS AND CAPACITY

Weight, 1,200 lb.
Floor space, 3 ft. 8 in. x 2 ft. 8 in.
Capacity of drum, 2,000 lb. on a single line.
Drum: Diameter, 6 in.; between flanges, 19 in.
Elevator sheave, 24 in. diameter; capacity, 400 lb. lift.
Hoisting speed, 150 ft. per minute.
Hp. required, 5.
Complete with winch head, drum, elevator, and pulley, but not belt nor engine, $325.

Compressed Air Hoist. A hoist intended for light lifting work, having a capacity of one-half ton, is adaptable to various kinds of hoisting, such as materials and tools in structural work, placing concrete forms, laying sewer pipe, drain tile, etc., and for moving dump cars over a limited distance, etc. It will accommo-

Fig. 195. Air Operated Hoist for Construction Work.

date a length of 700 ft. of $\frac{1}{4}$-in. rope or 450 ft. of $\frac{5}{16}$ rope. The capacity is 1,000 lb. at a rope speed of 85 ft. per min. at a pressure of 85 lb. It will operate on either compressed air or steam, has a single drum, moving parts except drum enclosed, weighs less than 300 lb. and costs $350.

Traction Power Hoist. A light self-propelled power hoist capable of lifting 3 tons at a radius of 9 ft. is operated by a gaso-

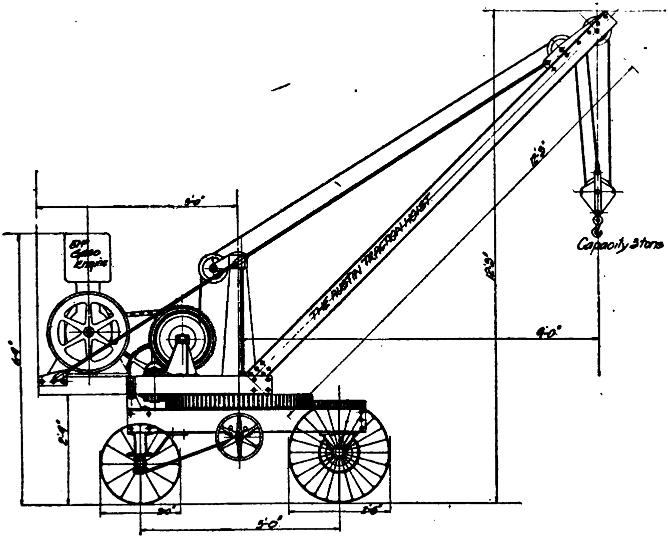


Fig. 196. Traction Power Hoist.

line engine with friction clutch controls for hoisting, swinging and traveling. The fuel estimate is 6 gal. of gasoline per 10 hrs. The traction speed is from ½ to 1 mile per hr. The shipping weight complete is about 5,650 lb., and the price is $2,800 f. o. b. Chicago.

SECTION 47

HOISTS

Material elevators constructed so that one platform is moving up at the same time the other is moving down are built of wood reinforced with iron. The price includes all the necessary sheaves and 3/8-in. 6 x 19 crucible steel rope.

Length of Guides (Ft.)	Weight in Lbs. With Guides	Weight in Lbs. Without Guides	Price With Guides	Price Without Guides
80	2,200	1,200	$210	$147
95	2,400	1,200	224	154
110	2,600	1,200	237	160
120	2,700	1,200	250	167
135	2,800	1,200	262	173
150	3,000	1,200	275	180

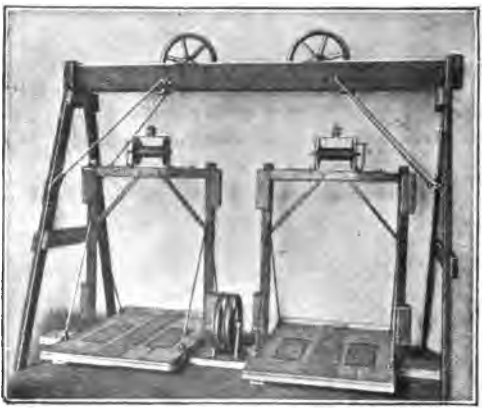


Fig. 197.

The following table is for single platform material elevators with wooden platforms.

Length of guides in ft.	Price with guides	Price without guides
80	$115	$ 86
95	122	90
110	128	93
120	134	96
135	141	99
150	147	103

The following prices are for single platform material elevators with steel platforms 6 ft. by 6 ft.

Length of guides in ft.	Price with guides	Price without guides
80	$230	$201
95	236	205
110	243	208
120	250	211
135	256	214
150	262	218

These elevators may also be had in lengths of 40, 55 and 65 ft. at corresponding prices.

A single or double cage elevator without cable, cable sheaves, or sheave bearings costs $110 and weighs 910 and 940 lb. respectively, for shipment. Upper sheaves with bearings cost $10.60 each and the lower sheaves with bearings cost $4.75 each. The double cage elevator is similar to the one shown in Fig. 197. It has two cages 3 ft. by 6 ft. The single cage elevator has a cage 5 ft. 6 in. by 6 ft.

A light traveling elevator illustrated by Figs. 198 and 199 was described in Vol. 71, No. 24 of *Engineering Record* by Mr. Robert Shannon. He states that this rig has cheapened by 40 to 50 cents per cu. yd. the cost of placing relatively small volumes of concrete in piers and floors of building work. This saving per cubic yard is over the cost of doing similar work with a distributing system depending on a tower elevator. A complete elevator of this kind, including the skip, has been built for less than the cost of the average tower alone of the same height. One of these towers, 35 ft. high, has been set up and material handled on it 45 min. from the time it arrived on the job. The elevator is rolled along on a track beside the wall, floor or pier forms into which it is delivering, saving wheeling materials on long runs. It is built in 12-ft. spliced sections, and can be easily knocked down and taken to another contract or to another part of the job. The one illustrated has a 5-cu. ft. skip, and was used with a portable mixer mounted on a truck which discharged directly into the skip. The concrete mixer was built with a special hoist added for the purpose of hoisting lumber and forms, as well as concrete, so that it is a combined mixer and hoist.

A separate gasoline hoist, however, may be used with this ele-

vator, and it or the mixer or both moved only at intervals. In this event concrete may be carried to the skip in carts. On one job where the line needed to reach the extreme position of the elevator was too long to be coiled on the drum of the hoist when

Fig. 198. Elevator in Use.

the elevator was near by, the end of the rope was coiled up and clamped above the bail of the bucket.

Where the elevator is moved and the hoist remains stationary, it is impossible to mark the cable so the engineer can tell when the skip is in a dumping position. Neither is it always possible for the engineer to see the skip in this position. In place of

having the ordinary bell, pulled with a wire by some one on top of the form, an electric contact device mounted on the guides on which the bottom wheels of the skip run rings a signal at the hoist when the skip reaches the dumping position, and discharges its load. This device, made of a brass spring and contact fastened on with carpet tacks, is shown in the accompanying drawing.

The elevator is shown arranged as an A-frame straddling a series of pier forms or a wall form in the drawing. It may also be used without the back legs and the second track by leaning it

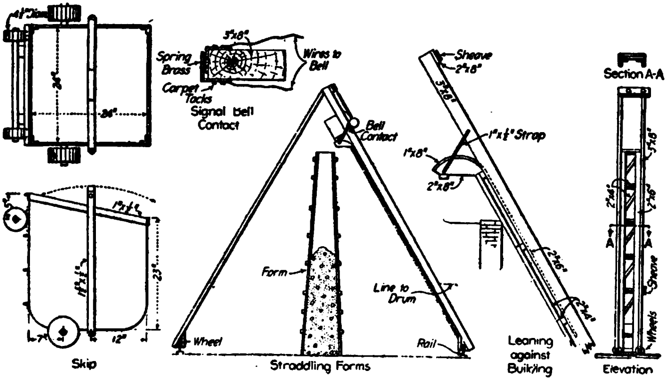


Fig. 199. Details of Traveling Elevator.

against the form work or against the site of the building. As it is very light, it is easy for one or two men in the latter case to hold it out from the building while it is being rolled along the track. It may also be held out from the building by a guy line attached to its top. The elevator has been used in the construction of the Danforth Theatre, a swimming pool known as the Peoples Palace and several other buildings in Jersey City.

SECTION 48

HORSES AND MULES

The price of horses and mules varies very greatly with the locality, season of the year and also from year to year. Generally speaking, a good horse or mule costs from $200 to $350. A mule weighing 1,100 lb. will do as much work as a horse weighing 1,400 lb., and is less liable to sickness, can stand harder treatment, and eats slightly less than a horse. Twenty-eight mules bought in Kentucky and Missouri in 1910 were of an average weight of 1,100 lb., average age 6 years and cost on an average of $255, including expenses of transporting to New York. As a rule a mare mule is more desirable than one of the other sex. A freight car load of horses or mules contains 22, an express car load 28. It takes about three weeks to acclimate a green animal. The annual depreciation of a horse used on construction work is about 15%. In figuring the cost of feeding horses on construction work it should be appreciated that the horses will eat hay the whole year round, while they will require grain only during the period when they are actually working. Hay necessary for one horse for one day is 14 lb. of hay grown by irrigation or 22 lb. of cultivated timothy and red top or 30 lb. of native hay. One horse or mule eats as much as three burros or jacks.

The average daily feed of each horse or mule used by the H. C. Frick Coke Company during a period of six years was 26 ears of corn (70 lb. per bu.), 6 qts. of oats and 16½ lb. of hay. A water supply sufficiently large to give 14 gallons of water to each horse should be allowed for.

In the southern portion of the United States horses on large jobs may work almost every day, but in the north it is ordinarily possible to obtain 180 days' work each year only.

In a Brooklyn St. Ry. cost of feeding 2,000 horses was $20.00 per month each prior to 1910 and the depreciation per horse was considered to be 25% per annum. Besides about 4 gallons of water per day each animal consumed the following amounts of food:

Feed Consumed.	Total (lbs.)	Pounds per Horse.	Cost per Horse.	Per Day.
Oats	14,281,172	7,690	$108.50	$0.2975
Hay	9,991,330	5,385	48.75	.1334
Straw	1,893,633	1,020	7.72	.0198
Bran	775,396	418	4.26	.0116
Meal	95,041	51	.85	.0023
Salt	122,267	66	.46	.0012
Corn	29,219	16	.25	.0007
Totals, prior to 1910			$170.79	$0.4665

According to some records in Manhattan, Bronx and Brooklyn, the cost with the average number of horses kept for this period were as shown below, the costs and averages being figured on the basis of 365 days per year:

	Manhattan.	Brooklyn.	Totals and Averages.
Average number of horses kept	1,174	681	1,855
Stable rental	$ 41.44	$ 19.94	$ 33.50
Stable labor	237.00	268.00	248.00
Feeding and bedding	171.00	171.00	171.00
Shoeing	18.36	17.75	18.12
Veterinary	5.63	9.08	6.89
Totals, prior to 1910	$473.43	$475.77	

Mr. Richard T. Fox of Chicago, in a report to the Street Cleaning Department of Boston, gives the following figures:

Total number of horses owned by the department	128
Maintained directly by the department	95
Boarded by the Sanitary Department	33
Net cost per horse per year for rent, repairs, shoeing, veterinary services, medicine and feed, prior to 1910	$517.83

Mr. Fox found that S. S. Pierce & Co., wholesale grocers of Boston, paid $27.65 per horse per month for maintenance and shoeing, veterinary services and boarding in a public stable.

For shoeing, the Street Cleaning Department's bill amounted to $33.43 per year per horse. He found that Pierce & Co. paid a little less than $12.00 per year for veterinary services and medicine.

In constructing the water purification works at Springfield, Mass., the teaming and horse work was done mainly by teams owned by the company or hired and kept by it. The greatest number of horses owned was 43 and the greatest number hired and kept was 10. Hired horses cost $1.00 per day per horse for rent. A stable 100 ft. long by 30 ft. wide was constructed, and the equipment consisted of 20 bottom dump wagons, 6 wheel scrapers, caravans, express wagons, etc. The roads were in bad shape and had very heavy grades. All the horses were young

and cost on an average $230 each, cost of shoeing and keeping these horses, including all expenses, was as follows:

COST OF TEAMING WORK — 72,474 HORSE-HOURS

Buildings.		Per Horse-hour.
Cost of materials used in building stable		$0.006
Cost of labor on same		.0033
Cost of proportion of material used in blacksmith shop		.0001
Cost of labor on same		.0010
Total cost of buildings		$0.0104
Depreciation and Repairs:		
Cost of depreciation on horses, including freight		$0.041
Cost of depreciation on harnesses and repairs on same		.01
Cost of depreciation on wagons and repair parts for same		.01
Cost of labor on wagon repairs		.0036
Total cost of depreciation and repairs		$ .0646
Cost of insurance		$0.006
Cost of rent paid for hired horses		.02
Cost of teamsters and barn men		.1137
Cost of labor shoeing	$0.0055	
Cost of materials shoeing	.002	.0057
Cost of fodder of all kinds		.0845
Grand total cost of keeping horses per horse-hour actually used		$0.3067
Cost of single teams per hour		$0.39
Cost of double teams per hour		.605

The entire cost of the stable and a fair proportion of the cost of the blacksmith shop is charged against this one season's work. Had the horses been kept for the two seasons, the figure would have been reduced one-half.

The depreciation on the horses represents the value of five horses lost and shrinkage in value of the remainder after one season's work. This figure would also probably show some improvement if extended through two or more seasons.

The wagons received rather severe usage under the steam shovel, and repair bills were correspondingly large.

A 4-horse team averaged 16½ miles per day over fine macadam roads as follows:

	Case I.	Case II.
Loads per day	14	7
Length of lead, ft.	3,000	6,200
Level, ft.	2,400	2,400
5% Grade, ft.	600	3,800
Gross load, tons	3.65	3 15
Ton	0.65	0.65
Net load, tons	3.00	2.50
Tractive force on level, lb.	255.5	220.5
Tractive force on 5% grade, lb.	646.0	578.0
Duty per day, foot pounds	16,000,000	21,000,000

Mr. H. P. Gillette has maintained teams at the following per month per team:

½ Ton of hay, @ $10.00	$ 5.00
30 Bu. of oats, @ 35 cents	10.50
Straw for bedding	1.00
Shoeing and medicine	2.00
	$18.50

Twenty-five horses working for a period of 12 months on road construction in San Francisco, cost per horse per day as follows:

28 Lb. wheat hay	@	$15.50 per ton	$0.215
12 Lb. rolled barley	@	24.10 per ton	0.150
1½ Lb. oats	@	27.40 per ton	0.020
¼ Lb. bran	@	2.20 per ton	0.003
1⅛ Lb. straw bedding	@	13.80 per ton	0.009
			$0.397
Wages of stableman ($775 for 12 mos.) and hauling forage ($281 for 12 mos.)			0.113
Total, prior to 1910			$0.510

COST OF MAINTAINING CITY OWNED TEAMS

Interesting data on the maintenance of horses by municipal departments are given in a recently issued report by the Rochester Bureau of Municipal Research, Inc., on the collection of refuse in the City of Rochester, N. Y.:

Cost of Maintaining Horses at Columbus, O. According to the report of Superintendent E. W. Stribling, of the Division of Garbage and Refuse Collection, the cost of maintaining 142 horses by the city of Columbus, O., in 1916 was 83.7 ct. per horse per day. This included a cost of 41.63 ct. for feed; 13.53 ct. for veterinary services, shoeing and supplies; and 28.54 ct. for stable labor. In 1915 the unit cost was 83 ct. per horse per day, including 45.77 ct. for feed, 11.98 ct. for veterinary services, shoeing, and supplies and 25.25 ct. for stable labor. The labor force consisted of 16 men and a night watchman. The cost of feed was about $14 per ton for hay, 75 ct. per bushel for corn and 50 ct. per bushel for oats. Straw cost about $7 per ton. In 1916 each horse consumed daily 30 lb. of hay, and 13 lb. of grain, 5.3 lb. of straw were used in bedding each horse. In 1915 these quantities were 31 lb., 12.75 lb., and 6.3 lb. respectively.

Cost of Horse Maintenance at Cincinnati. Similar costs for 1916 in the city of Cincinnati, given in the report of Fred Maag, Superintendent of the Department of Street Cleaning, Sewer and Catch Basin Cleaning, indicate that 34.9 ct. per horse per day was the cost of feeding and 39.4 per ct. was the cost of "other stable expenses," the total cost being 74.3 ct. per horse per day. Approximately 190 horses and 80 mules were maintained in 17

stables, practically one-half of this number being boarded in one stable. Each horse consumed 14.7 lb. of hay, 11.5 lb. of oats and 2.8 lb. of nutritia daily. Hay cost about $18 per ton, oats 45 ct. per bushel and nutritia $1.50 per hundredweight. (No allowance apparently was made for bedding straw.)

Cost of Feeding Horse at Washington. In Washington, D. C., according to the report of the Engineering Department for the fiscal year, 1915–16, the cost of feed amounted to 40.2 ct. per horse per day. The daily allowance per horse was 3.3 lb. of dry straw, 7 lb. of long timothy, 7 lb. of mixed clover hay, 12.8 lb. of oats and 1.7 lb. of bran. Straw cost at the rate of $16, long timothy at $20.80 and mixed clover hay at $20 per ton, oats at 54 ct. per bushel and bran at $1.27 per hundredweight. The cost of shoeing was stated to be 2.6 ct. per horse per day.

Cost of Maintaining Horses by New York Street Cleaning Department. In the annual report of the Department of Street Cleaning of New York, in 1916, Commissioner J. T. Fetherston states that the cost of "labor, materials, supplies and consumable equipment used directly in the care of horses" amounted to $1.087 per horse per day and that this cost represents prices of forage and supplies considerably above normal. About 64% of the total cost represents the cost of forage, 30% the direct labor cost and 6% the cost of maintaining stable equipment. In the 26 stables maintained by the department, 2,400 horses were cared for. One hostler and one stableman were employed for each 13 horses. In 1917, the daily allotment for each horse was 23 lb. of oats, 18 lb. of hay, 3¼ lb. of bran and 3 lb. of straw. In addition to this each horse was given 1½ lb. of coarse salt and 2½ lb. of rock salt per month. When idle the horses were given half ration of oats. In 1916, the daily ration was 21 lb. of oats, 15 lb. of hay and 1¼ lb. of bran. The other items were practically the same as for 1917. This appears to be an unusually heavy ration and the cost of feed alone was practically 70 ct. per horse per day.

Stable Costs at Rochester. For Rochester it was possible to obtain from James M. Harrison, formerly superintendent for the Genesee Reduction Co., data of the cost of maintaining horses employed in garbage collection from 1908 to 1916. On Jan. 1, 1917, the Department of Public Works took over the operation of the garbage plant stables and the 1917 costs, therefore, are available also.

In 1917 the 68 horses quartered at the garbage plant stables cost about 68 ct. per horse per day to maintain. The approximate cost of feed amounted to 50.7 ct.; the direct labor cost of stable operation, 9.4 ct; and the estimated cost of barn supplies, shoeing and harness repairs, 7.9 ct. per horse per day. No exact

ration allotment was made, but according to the total quantities purchased during the year each horse consumed about 11 lb. of oats and 22 lb. of hay per day. The approximate average cost of oats was 80 ct. per bushel and the cost of hay was about $18 per ton. The stable force consisted of one barnman and three helpers, the barnman and one helper working seven days and the other two helpers six days per week. The drivers cleaned and harnessed the horses and gave them their noon feeding.

The foregoing data and certain additional data as to the cost of maintaining horses by the Genesee Reduction Co. before 1917, are shown in Tables I and II.

From the foregoing and other data it appears that a horse used in collection work should be fed on the average about 20 lb. of hay and 14 lb. of oats per day, in addition to possibly 2 lb. of other feed, consisting principally of bran, salt, etc. Also each horse should be bedded with approximately 5 lb. of dry straw daily. On this basis and with hay costing $18 per ton, oats 80 ct. per bushel, other feed $1.50 per hundredweight and straw $12 per ton, the total daily cost per horse of feed and bedding would amount to the following:

20 lb. of hay at $18 per ton	$0.18
14 lb. of oats at $0.80 per bu.	.35
2 lb. of other feed at $1.50 per cwt.	.03
5 lb. of straw at $12 per ton	.03
Total estimated cost of feed and bedding per horse per day	$0.59

In addition to this the cost of veterinary services, maintenance of stable equipment and supplies, shoeing, and harness repairs should not exceed 12 ct. per horse per day. If one hostler at $800 per year and one stableman at $750 per year were provided for every 20 horses, the direct labor cost of stable operation would amount to about 21 ct. per horse per day. This would include the cost of all work involved in feeding, bedding, cleaning and otherwise caring for horses, and all labor about the stables such as cleaning stables, handling and moving equipment, cleaning equipment, etc.

The total cost per horse per day, therefore, might be estimated at 92 ct., distributed as follows:

Feed and bedding	$0.59
Veterinarian, shoeing, harness repairs, etc.	.12
Direct labor cost of stable operation	.21
Total maintenance cost per horse per day	$0.92

The annual cost of maintaining horses at this figure would be $336.65 per horse, exclusive of the cost of overhead super

vision; fixed charges on first cost of horses, stable sites and stable buildings, depreciation of horses, and depreciation and maintenance of stable buildings.

The annual (purchase) cost of the horses used in garbage collection in Rochester since 1912 has been about $31 per horse, which includes replacements as well as the purchase of three horses during the six years in addition to the number owned at the beginning of the period. (See Table II.)

TABLE I — COST OF FEEDING HORSES EMPLOYED IN THE COLLECTION OF GARBAGE IN ROCHESTER, N. Y., 1908 TO 1916

Year	Total cost of feed (grain, hay, straw)	Approximate number horses fed.	Average cost per horse per day.
1908	$ 7,364.08	40	$0.505
1909	6.964.89	40	.477
1910	6,912.67	40	.474
1911	6,827.04	40	.467
1912	7,816.29	65	.330
1913	9,269.83	65	.395
1914	8,771.77	65	.370
1915	10,666.02	66	.443
1916	9,570.47	66	.397

TABLE II — COST OF RENEWALS OF HORSES EMPLOYED IN THE COLLECTION OF GARBAGE IN ROCHESTER, N. Y., 1912 TO 1917

Year.	Total expenditure for horses.	Approximate number of horses.	Average cost per horse per year.
1912	$2,219	65	$34
1913	1,885	65	29
1914	4,205	65	65
1915	1,020	66	15
1916	1,575	66	24
1917	1,125	68	17

Estimates as to the economic life of a horse used in collection work vary from 4½ to 8 years. It is believed, however, that a good horse should give at least six years of useful service in this kind of work. Assuming a first cost of $275 and a salable value of $75 at the end of six years, the annual depreciation would be $33.33 per year per horse.

Cost of Horse Maintenance at Boston, Mass. The average cost in 1918 of maintaining the horses of the sewer and sanitary division of the Public Works Department of Boston, Mass., was $1.68 per day per horse, according to the recently issued annual report of the department. An average of 171.8 horses was kept. The itemized cost was as follows:

	Per horse per day.
Labor	$0.5837
Hay and grain	.8355
Fuel	.0087
Light	.0056
Rent and taxes	.0500
Yard and stable repairs	.0187
Yard and stable furnishings	.0285
Veterinary services and medicine	.0225
Horseshoeing, etc.	.1292
Total	$1.68

Rules for Pack Animals. Material packed on animals should be divided into two equal portions and slung on each side of the back. A fair load for a horse is 300 pounds, for a mule 200 to 300 pounds, for a burro 100 to 150 pounds, for a South American llama 50 to 75 pounds. However, the proper load for a pack animal varies with the size of the animal and the condition and grade of the road to be traveled.

Table for Estimating the Cost of Teaming. The accompanying table prepared by Mr. E. B. Hiatt, engineer of Madison County, Iowa, has been of service in estimating the cost of team hauling on work for that county. The figures are based on a rate of travel of 2 miles per hour with loads and 3 miles per hour returning empty. Forty minutes is allowed for loading and unloading 3,750 lb. with shovels. This weight was the average load, season of 1918. The vehicle considered was a common farm wagon. A comparison of the schedule with the flat rate of 1 ct. per bushel per mile for hauling wheat in northern Iowa and southern Minnesota shows that at 11 miles the rates are practically the same, while at 5 miles the county would pay $.138 more, and at 15 miles $.085 less.

SCHEDULE OF PRICES FOR HAULING ONE TON

	Team rates per day of ten hours.					
Miles.	$5.00	$5.50	$6.00	$6.50	$7.00	$7.50
0.5	.288	.317	.346	.375	.404	.433
1.0	.400	.440	.480	.520	.560	.600
1.5	.511	.562	.613	.664	.715	.766
2.0	.622	.684	.746	.808	.871	.933
2.5	.733	.806	.880	.953	1.026	1.100
3.0	.844	.928	1.013	1.097	1.182	1.266
3.5	.955	1.051	1.146	1.242	1.337	1.433
4.0	1.066	1.173	1.280	1.386	1.493	1.600
4.5	1.177	1.295	1.413	1.531	1.648	1.766
5.0	1.288	1.417	1.546	1.675	1.801	1.933
5.5	1.400	1.540	1.680	1.820	1.960	2.100
6.0	1.511	1.662	1.813	1.964	2.115	2.266
6.5	1.622	1.784	1.946	2.108	2.271	2.433
7.0	1.733	1.906	2.080	2.253	2.426	2.600
7.5	1.844	2.028	2.213	2.397	2.582	2.766
8.0	1.955	2.151	2.346	2.542	2.737	2.933

8.5	2.066	2.273	2.480	2.686	2.893	3.100
9.0	2.177	2.395	2.613	2.831	3.048	3.266
9.5	2.288	2.517	2.746	2.975	3.204	3.433
10.0	2.400	2.640	2.880	3.120	3.360	3.600
10.5	2.511	2.762	3.013	3.264	3.515	3.766
11.0	2.622	2.884	3.146	3.408	3.671	3.933
11.5	2.733	3.006	3.280	3.553	3.826	4.100
12.0	2.844	3.128	3.413	3.697	3.982	4.266
12.5	2.955	3.251	3.546	3.842	4.137	4.433
13.0	3.066	3.373	3.680	3.986	4.293	4.600
13.5	3.177	3.495	3.813	4.131	4.448	4.766
14.0	3.288	3.617	3.946	4.275	4.604	4.933
14.5	3.400	3.740	4.080	4.420	4.760	5.100
15.0	3.511	3.862	4.213	4.564	4.915	5.266
15.5	3.622	3.984	4.346	4.708	5.071	5.433
16.0	3.733	4.106	4.480	4.853	5.226	5.600
16.5	3.844	4.228	4.613	4.997	5.382	5.766
17.0	3.955	4.351	4.746	5.142	5.537	5.933
17.5	4.066	4.473	4.880	5.286	5.693	6.100
18.0	4.177	4.595	5.013	5.431	5.848	6.266
18.5	4.288	4.717	5.146	5.575	6.004	6.433
19.0	4.400	4.840	5.280	5.720	6.160	6.600

SECTION 49

HOSE

Rubber water hose, regular construction.

	Price per Foot ½ Inch Diameter.	Price per Foot 1 Inch Diameter.
2 Ply	$0.14	$0.17½
3 Ply	.17½	.28
4 Ply	.21	.35
6 Ply	.31½	.53

Diameters run from ½ inch to 8 inches.

Rubber steam hose, regular construction.

	Price per Foot ½ Inch Diameter.	Price per Foot 1 Inch Diameter.
3 Ply	$0.32	$0.49
4 Ply	.39	.60
5 Ply	.49	.74
6 Ply	.59	.90
7 Ply	.69	1.05
8 Ply	.79	1.20

Diameters run from ½ inch to 3 inches.

The following table shows the proper ply hose for pressures of from 30 to 100 pounds:

		Heat generated				
30 Lb.	=	274°	¾" 3-ply	1" 4-ply	1¼" 4-ply	1½" 5-ply
50 Lb.	=	298°	¾" 4-ply	1" 5-ply	1¼" 5-ply	1½" 6-ply
60 Lb.	=	307°	¾" 5-ply	1" 5-ply	1¼" 6-ply	1½" 6-ply
80 Lb.	=	324°	¾" 5-ply	1" 6-ply	1¼" 7 ply	1½" 8-ply
90 Lb.	=	331°	¾" 6-ply	1" 6-ply	1¼" 8 ply	1½" 9-ply
100 Lb.	=	388°	¾" 6-ply	1" 7-ply	1¼" 8-ply	1½" 10-ply

Seamless cotton rubber lined hose.

Internal diam.	1"	1¼"	1½"	2"	2¼"	2½"	3"	3½"	4"
Price	$0.24	$0.31	$0.35	$0.42	$0.46	$0.49	$0.70	$1.05	$1.90

These prices do not include couplings. Unlined linen hose costs about half of the above.

Coverings for rubber hose designed to protect it from excessive wear may be woven cotton, wire wound, marlin woven or marlin wound. The disadvantages of various covers are as follows: In wire wound hose the wire is liable to cut the hose when the

latter is stretched, woven cotton and marlin absorb moisture and rot, marlin wound covering is liable to become loose as soon as one strand is cut. These coverings add about 15% to the price of plain hose.

Metal tube hose consists of a metal armor with asbestos packing and a rubber coating. It is adapted for use with steam, gas, oil, or any fluid which has a tendency to cause rubber to deteriorate rapidly.

Size, diameter	½"	¾"	1"	1¼"	1½"
Price per foot	$1.25	$1.33	$1.68	$2.10	$2.50

A flexible metallic hose designed especially for hot water is a peculiarly prepared rubber cover with non-rustable metallic armor.

Size, diameter	1½"	2"	2¼"	2½"
Price, per foot	$0.98	$1.55	$1.75	$1.95

A flexible metallic hose designed to withstand the action of oil and air and fitted for rough service is covered with braided wire.

Size, diameter	¼"	½"	¾"	1"	1¼"	1½"
Price, single cover ..	$0.25	$0.35	$0.42	$0.62	$0.97	$1.10
Price, double cover..	.31	.42	.52	.75	1.10	1.35

An especially strong flexible hose is armored inside and out, adapted for hard service with drills, etc.

Size, diameter	½"	¾"	1"	1¼"	1½"	1¾"	2"	2½"	3"
Price, per foot	$0.63	$0.77	$0.98	$1.10	$1.35	$1.75	$2.10	$2.30	$3.50

Suction hose reinforced spirally with flat wire is made with smooth bore for use on large dredges and centrifugal pumps and rough bore for use on diaphragm and small steam pumps.

Internal diameter	¾"	1"	1½"	2"	3"	5"
Price per foot, rough bore...	$0.31	$0.50	$0.84	$1.30	$2.20	$4.20
Price per ft., smooth bore...	.45	.56	.95	1.50	2.50	4.70

Internal diameter	6"	8"	10"	12"	15"	20"	21"
Price per foot, rough bore	$5.30	$8.40	$11.20	$11.30			
Price per foot, smooth bore	5.90	8.90	12.50	15.00	$22.00	$38.00	$42.00

SECTION 50

HYDRAULIC MINING GIANTS

The nozzles first used in hydraulic mining ranged from plain pipe or hose to simple nozzles. The first improvement in discharge pipes was a flexible horizontal iron joint formed by two elbows, one working over the other, with a coupling joint between them. These elbows were called "Goose Necks." These joints were very defective, the water pressure causing them to move hard and "buck." The evolution of the hydraulic nozzle was from the "Goose Neck" to the "Globe Monitor"; then, successively, the "Hydraulic Chief," "Dictator," and "Little Giant." The "Hydraulic Giant" is a modification of the Little Giant, and is shown in Fig. 200.

Fig. 200. Hydraulic Mining Giant.

Under high pressure the "deflector," which is fitted to the butt of the discharge and carries the nozzle, should be used. By means of the "deflector" the Giant can be turned with the greatest ease. In the table of sizes, weights, etc., of Giants, the column headed "Approximate Amounts of Gravel Washed in 24 Hours" is based on the assumption that the water carries about 2.86% of solid material. This percentage varies widely and depends upon a number of conditions, but mainly upon the nature of the soil, direction of washing, and slope of the sluices. Under extremely favorable conditions it is possible to carry as large a percentage as 20 or 25, but in many cases the proportion of earth to water is as 1 to 200 or more.

DOUBLE-JOINTED, BALL-BEARING HYDRAULIC MINING GIANTS

Size Number.	Diam. of Pipe Inlets (Ins.)	Diam. of Butts with Nozzle Attachment. (Inches.)	Effective Head in Feet.	Size of Nozzle Supplied and Flow in Cubic Feet per Minute that Will Pass the Nozzles Under the Given Head.		Approx. Amount of Gravel (Average Ground) Washed in 24 Hours. (Cubic Yards.)		Weight of Heaviest Part. (Pounds.)	Shipping Wt. (Pounds.)	Approximate Prices. Double-Jointed. Ball-Bearing.	Approximate Prices. Deflectors.
				1" Nozzle	1½" Nozzle	1" Nozzle	1½" Nozzle				
0	5	2½	100	26.46	59.16	40	90	100	330	$145	..
			150	32.40	72.48	50	110				
			200	37.26	83.64	60	130				
				2" Nozzle	3" Nozzle	2" Nozzle	3" Nozzle				
1	7	4	100	101.88	236.22	160	370	120	390	185	$40
			200	148.32	334.08	230	520				
			300	181.61	409.20	280	640				
			400	209.82	472.50	320	730				
				3" Nozzle	4" Nozzle	3" Nozzle	4" Nozzle				
2	9	5	100	236.22	420.06	370	650	150	520	230	45
			200	331.08	594.00	520	920				
			300	409.20	727.56	640	1,130				
			400	472.50	840.12	730	1,300				
				3" Nozzle	4" Nozzle	3" Nozzle	4" Nozzle				
3	11	6	200	334.08	594.00	520	920	210	890	325	50
			300	409.20	727.56	640	1,130				
			400	472.50	840.12	730	1,300				

SECTION 51

JACKS

Plain Hydraulic Jacks

Capacity in tons	Maximum rise in in.	Weight in lb.	Price f. o. b. factory
4	9	34	$ 53
7	12	63	62
10	12	75	70
20	18	142	115
30	18	227	165
40	22	345	210

Broad Base Hydraulic Jacks

Capacity in tons	Maximum rise in in.	Weight in lb.	Price f. o. b. factory
4	9	48	$ 59
7	12	77	64
10	12	105	84
20	18	177	140
30	18	243	185
40	22	347	247

In the above types the plain jack is used where a firm rest or footing can be obtained for the base such as a cement floor, hard ground, wood, stone, etc. The broad base jack is used where a firm rest or footing cannot be obtained for the base, or where the load is unsupported and steadiness is required. It is used largely under locomotives, cars, etc.

A screw jack operated by a lever, of either the worm gear or bevel gear type costs as follows: (Lift 10 inches.)

Capacity in tons	Weight in lb.	Price f. o. b. factory
15	70	$ 42
25	75	63
35	80	91
50	111	105
75	144	225
100	199	193

Locomotive jack screws cost, f. o. b. Chicago, as follows:

Capacity in tons	Height overall in inches	Price
10	8	$ 3.00
12	10	4.30
16	12	5.60
20	14	7.40
24	16	9.90
28	18	13.00
36	20	21.00

SECTION 52

LEAD

Lead costs about 8 cents per lb. in ton lots.

Lead Wool is put up in strands which should be placed in the joint one at a time and each strand thoroughly calked before the next strand is added. It is extremely valuable where the trench is wet or where the pipe is under pressure, as it can be used under water, whereas molten lead cannot. Calking is somewhat difficult if ordinary methods are pursued, but by the use of an outfit such as is described under "Air Compressors" this difficulty is obviated. The manufacturers claim a saving in amount necessary to calk a joint as compared with cast lead, as shown by the following:

Diam. of pipe, inches.....	3	4	6	8	10	12	16	20	24	30	36
Cast lead required, Pounds	5	6	9	13	17	20	30	40	65	90	103
Maximum amount of lead wool required, Pounds	.	.	6	10	12	14	20	28	40	60	65

It costs, in lots of not less than 200 lb., including calking tools, 11¼ cents per lb., and in ton lots 10¾ cents per lb., f. o. b. New York. (See Air Compressors.)

Leadite, a substitute for lead used in jointing cast iron water mains, comes in powder form, packed in sacks of 100 lb. and barrels of 350 lb. One ton of this material is equivalent to four tons of lead and requires no calking. Price for less than car load, 12 cents per lb., f. o. b. Philadelphia.

Cost of Pneumatic Calking of Lead Joints. *Engineering and Contracting*, Dec. 17, 1913, gives the following:

In work done in New York City in 1910 for the Consolidated Gas Co., on a 48-inch line about 750 joints were calked with compressed air. These joints were air calked at a cost of about $5.30 per joint. The cost of hand calking would have been about $7.90 per joint, so there was a saving per joint of $2.60. On the 36-in. line the cost of air calking was $2.15 per joint, including labor costs, cost of operating compressor, cost of yarning and depreciation on the outfit. The cost per joint of calking by hand on this line would have been about $3.17. This gave a saving per joint in favor of compressed air calking of $1.02 or about 32% — very close to the average percentage of saving on

the 48-in. work. On the 30-in. work a pair of calkers, with a little practice, could air calk five joints per day as against two joints by hand. This gave a saving of about 30% in the expense for calking.

Since the foregoing data were given out by Mr. Colin C. Simpson in 1910 the cost of pneumatic calking has been reduced materially. The decrease in cost has been due largely to the improvements in the air hammer for calking purposes which have reduced air consumption and increased the efficiency of the tools.

It has been demonstrated repeatedly that lead wool joints calked by a pneumatic hammer are tighter than hand-calked joints, and that the time and expense of making the joints is at times cut in half by the use of air. Even better records have been made. Mr. Charles Dougherty gives the following data on a comparative test of pneumatic and hand-calked joints.

A test was conducted in the presence of representatives of various gas and water companies, from the vicinity of Boston, in the yards of the Malden Gas Co., at Malden, Mass., to determine the relative efficiency of a hand and pneumatically calked joint for high pressure water service. About 15 miles of such high pressure pipe is to be laid for the fire department of the city of Boston. These mains will be under a continuous hydrostatic pressure of 300 lb.

A special hub and cap with a special double groove high pressure joint was provided by the water department, for pneumatic calking, against time. The demonstrator first yarned the joint with about 1½ in. of hemp rope, the remainder of the space being filled with lead wool and calked, strand by strand, in a total time of two hours. This included the preparation of the yarn and lead wool for insertion in the joint. The hammer used a calking iron with a round shank.

The record made is noteworthy as compared with calking a similar joint by hand. Past records show that with two men it required an average of two days, of 8 hours each, to complete such a joint, making about 32 hours per man, by hand.

After the calking had been completed, the joint was submitted to a test, under the direct supervision of the water department, calibrations were made at different pressures, so as to determine the expansion of the joint under varying conditions, up to a point when it showed a tendency to pull away. Up to a pressure of 600 lb. there was no leak apparent, although the joint had spread considerably, about .015 of an inch. The test for tightness shows up very much in favor of the pneumatically calked joint, as similar joints made with cast lead and calked by hand, would raise as much as 1⅜ in. under a pressure of 600 lb.

The above mentioned test was made under rather adverse conditions. In the first place, the hammer used had been in service a number of years. In addition the calking irons provided were not of just the right size or shape for the special joint under test; as a result a great deal of time was lost in the calking of the joint.

The results of this test show that the pneumatic calking process is faster and at the same time gives a better joint than hand calking, using lead wool, and that it is also far superior to poured lead joints whether hand or pneumatically calked.

Cast Lead Joints.—A test was made for the Department of Water Supply, Gas and Electricity of New York City, of the efficiency of pneumatically calked cast lead joints with the results here described. The joints selected for tests were on a 36-in. line. One cap and one regular pipe joint were calked by pneumatic tools and one cap by hand.

The time to calk the cap by the pneumatic tool, including the cutting off of the slug or lip, which weighed 7 lb., required 30 minutes, while the ordinary joint required only 22 minutes. The difference in time of eight minutes is doubtless due to the fact that the operators had to work between the four extension bolts that were provided as a means for retaining the caps. The joints calked by the pneumatic tool contained an average of 120 lb. each of lead. The air pressure used was 70 lb. The standard 1½-in. yarn with 3½ in. of lead was likewise used. The cap calked by hand required 1 hour and 45 minutes to complete. Two men were used on each joint; that is, two hand men and two men with the pneumatic hammer.

After being completed and pronounced as satisfactory looking joints, the water test was applied by means of filling up the pipe sections and capping all outlets. The pump was started until a pressure of 200 lb. had shown when the hand-calked cap started to leak. The retaining bolts were then removed and the pump started again and the hand-calked cap let go entirely when the gage showed a pressure of 140 lb. The city's representative figured that the pressure exerted against each cap was 83 tons.

The caps were then removed entirely and a section cut from the hand-calked cap and the machine-calked cap. Inspection of these sections showed that the machine-calked cap was much denser and had likewise been pressed against the yarn so firmly that it required quite an effort of the fingers to separate the yarn from the lead. The hand-calked section did not show such a result.

SECTION 53

LEVELS

An engineer's dumpy level with an 18-inch telescope costs, with split tripod, \$115. The weight complete is 18 lb.

An engineer's Y level with an 18-inch telescope costs, with split tripod, \$140. The weight complete is 20½ lb.

Hand levels cost from \$4.00 to \$7.00.

A patented reflecting hand level costs about \$16.00.

An architect's or builder's dumpy level, with an 11-inch telescope, weighs 4 lb., and costs \$40. An architect's or builder's Y level, with an 11-inch telescope, weighs 5 lb., and costs \$50. With compass, \$65.

SECTION 54

LIGHT

Some construction work must be done at night, and much of it can be expedited if certain portions are done after the regular day shift has knocked off.

For instance, a macadam road must be finished in a limited time, the road to be surfaced is straight-away from the quarry, dock or siding where the stone is procured and the only economical way of hauling the stone is along the finished road. It is almost impossible, or at least very difficult, to use more than one gang. In such a case it is obvious that if the stone is unloaded, hauled and spread at night the work will be facilitated. There is no reason why this should not be done. Proper lights are necessary however.

Many steam shovels, cranes and derricks are operated at night. Darkness offers no obstacle to the working of cableways, belt conveyors and other conveying machinery if the loading and unloading places are properly illuminated. The means of lighting work may be anything from candles to electric light. Kerosene consumes five times and candles seven times as much

oxygen as acetylene. Kerosene gives off nine and candles ten times the product of combustion given off by acetylene. The light of kerosene and candles is obscured by the smoke given off by them; whereas, the light of acetylene and electricity is not thus interfered with.

CONTRACTORS' LIGHTS AND TORCHES

Contractors' lights are made in a number of different types of which we illustrate the most important.

Kerosene Burning Lights are made by several companies and the usual form consists of a cylindrical tank, with proper valves and feed pipes, and a support for the burner. They can be used for heating as well as lighting, and are very useful as paint burners, for boiler repairs, and for melting lead joints in water pipe.

Fig. 201. Kerosene Light.

A kerosene light and heating burner similar to the one shown in Fig. 201 costs as follows:

Candle power	Gal. of oil per hour	Approximate shipping weight in lb.	Price f. o. b. factory
2000	1	280	$115
4000	1½	285	125

Carriage for light, $22. Tripod attachment, $20. Wheel and hook attachment, $6.70.

Another kerosene light is made in three sizes, as follows:

Candle power	Gal. of oil per hour	Approximate shipping weight in lb.	Price f. o. b. factory
2000	1	80	$70
3000	1½	85	80
4000	2	90	90

Carbide Burning Lamps consist of an outer tank holding water, an inner tank holding carbides, and the pipe and burner. These lights are not usually affected by wind or rain and burn water and calcium carbide in about even proportions. Fig. 202 gives an illustration of this type of light. A light capable of burning six hours at an operating cost, manufacturers claim, of 5 cents

Fig. 202. Carbide Light.

per hour, is fitted with a single reflector. It weighs 63 lb. for shipment and costs $50.

A similar light capable of burning 12 hours at 5 ct. per hr. weighs 80 lb. for shipment and costs $55.

A light similar to the above but fitted with a double reflector and double burner capable of burning 12 hrs. at an operating cost of 10 ct. per hr., weighs 121 lb. for shipment and costs $75.

A hand light of the same make burns 8 hrs. at a cost of less than 1½ cents per hr. It weighs 14 lb. for shipment and costs $18.

Derrick light, capable of burning 12 hours at an operating

cost of 5 ct. per hr. provided with 21½ ft. of pneumatic hose and reflector, weighs approximately 100 lb. for shipment and costs $75 complete.

Carbide cakes for use in the above lights are to be had in 100 lb. drums and cost $6.50 per drum.

Cakes for the hand light are furnished in 75 and 40 lb. drums at a cost of $6.50 and $3.85 respectively.

All above prices are f. o. b. manufacturer's warehouse at point of shipment.

Another make of carbide lights cost as follows:

Candle power	Operating cost cents per hr.	Burning cap. in hours	Weight shipment, lb.	Price f. o. b. factory
8000	3	12	85	$ 70
12000	4½	12	85	85
15000	6–8	9	145	90
16000	8	10	137	110

Fig. 203.

Fig. 204.

Another lamp is illustrated by Fig. 204. This type is adapted to attachment on a steam shovel, crane, etc. It is rated at 15,000 candlepower and costs from 6 to 8 cents per hr. to operate. It weighs 140 lb. for shipment and costs $100 f. o. b. factory.

Carbide in drums of 100 lb. for the above lights costs about $7 per drum.

Gasoline Lights. A gasoline burning lantern rated at 200 candle power and stated to burn 15 hours on one quart of gasoline weighs 3½ lb. net and costs $7.50.

A hand searchlight rated at 5,000 candlepower, which throws a beam 50 ft. wide and 300 ft. long weighs 30 lb. and costs $63.

A portable flood light rated at 12,000 candlepower, stated to consume a gallon of gasoline in six hours, the rays covering an area of 250 by 400 ft., weighs 80 lb. for shipment and costs complete $126.

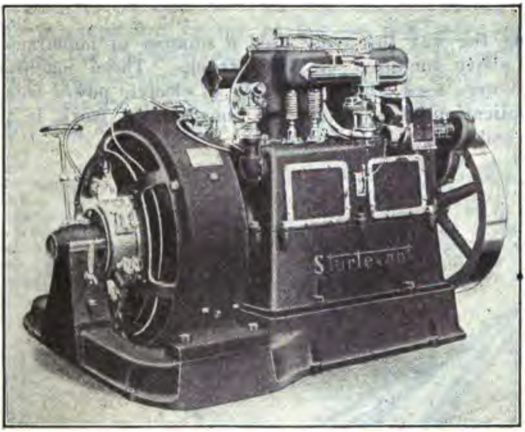


Fig. 205. Gasoline-Electric Generating Set.

Oil and Vapor Torches, familiarly known as banjo torches, consisting of a pan shaped tank for holding the kerosene or gasoline fuel, a gravity feed pipe, and a burner, for use in lighting small spaces are manufactured in many varieties, but are alike in the general method of operation. A novel use of these torches was for heating green concrete sewer pipe during cold weather.

Price with single burner $2.10. Double burner $3.25.

Electric Light Plant. An automatic plant consisting of a single cylinder 1.7 hp. 4 cycle gasoline engine, a generator, control board and starting battery arranged so that the unit can be started from a remote point, weighs approximately 500 lb. for shipment and costs $490 f. o. b. Michigan. This outfit is rated 750 watts at 110 volts and the manufacturer claims it will operate on a

load of 600 watts for 6 hours continuously on one gallon of gasoline. A load of 600 watts is obtained by burning 30 twenty watt lamps.

A gasoline-electric generating set illustrated by Fig. 205 is to be had in three sizes 5, 10 and 15 Kw. The 5 Kw plant will operate 200 twenty candlepower lamps. It weighs approximately 1,800 lb. for shipment and costs $3,000 f. o. b. factory.

The 10 Kw plant will operate 400 twenty candlepower lamps, it weighs approximately 3,000 lb. and costs $4,000 f. o. b. factory.

The 15 Kw plant will operate 600 twenty candlepower lamps, weighs about 4,000 lb. for shipment and costs $5,000 f. o. b. factory.

During the war the army used a number of machines similar to the above mounted on auto trucks. These machines thus mounted were used where flexibility of electric power was needed. The application of such rigs to construction work is practical where conditions will warrant it.

SECTION 55

LOCOMOTIVE CRANES

These machines are commonly steam driven, but may be had arranged for gasoline or electric drive. Steam cranes are usually equipped with double cylinder engines. The several motions of rotation, transfer on the track, moving the load and boom, are ordinarily accomplished by use of friction clutches; the engine then being of the non-reversing type. The boiler is placed behind the engine, thus serving to counterbalance the crane. The fuel and water tanks are also placed in the rear for the same purpose.

The following are the usual specifications:

Gauge of track	4 ft. 8½ in. or 8 ft.
Boiler pressure	100 lb. to 125 lb.
Cut-off	6/10 to 8/10 of stroke
Revolutions per min. (engine)	80 to 200
Car wheels	24 in. diam.
Track speed	300 to 500 ft. per min.
Track power, level track	3 to 4 loaded cars
Slowing speed	4 revolutions per min.

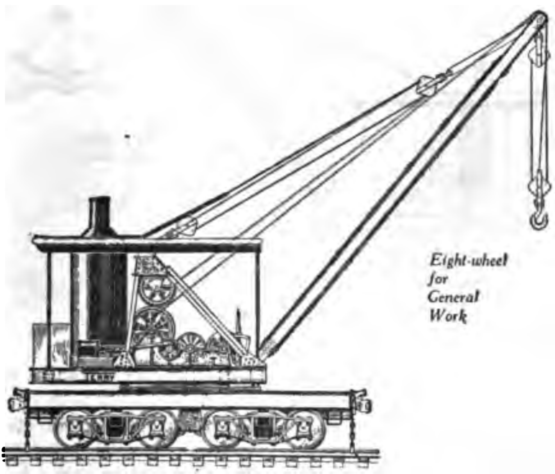


Fig. 206. 8-Wheel Type Locomotive Crane.

Owing to the limitations of the counterweight the crane will raise its greatest load when working at its shortest radius. These cranes are generally able to pull several loaded cars on level track. The boiler should be large in order to demand only occasional attention from the operator.

Locomotive cranes similar to the ones shown in Figs. 206 and 207 cost as follows:

STEAM DRIVEN — 4 WHEEL TYPE

Standard boom in ft.	Capacity in tons	Approximate shipping weight in lb.	Price f. o. b. factory
30	1- 6	32,000	$ 7,000
35	2-10	50,000	8,500
40	3-15	75,000	12,000

8 WHEEL TYPE

Standard boom in ft.	Capacity in tons	Approximate shipping weight in lb.	Price f. o. b. factory
30	1½- 8	44,000	8,000
35	2½-13	65,000	10.000
40	4 -20	100,000	14,000

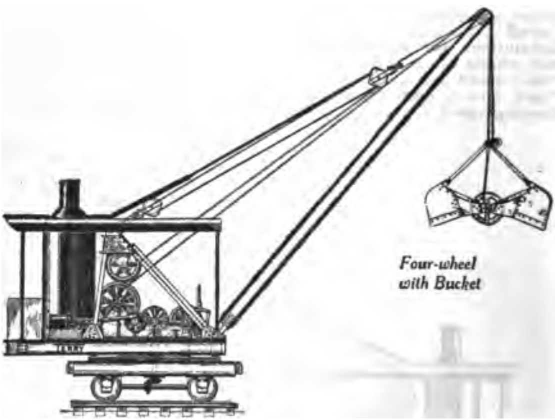


Fig. 207. 4-Wheel Type with Bucket.

In the above the maximum capacities are at a radius of 12½ ft. and the minimum capacities at 40 ft.

For prices of the above with oil burning boilers add 5%. For electric drive add 4%.

One type of locomotive crane is made in the following sizes:

No.	Rated capacity in tons	Type	Std. boom length	Approximate shipping wt. in lb.	Price f. o. b. factory
5	30–40	8 wheel	45 ft. 4 in.	136,000	$23,500
4	15–20	8 wheel	35 ft. 4 in.	87,500	14,000
2	10–12	4 wheel	31 ft. 5 in.	60,000	10,500
1	3– 5	4 wheel	20 ft.	30,000	7,500

Of the above, No. 1 is to be had with gasoline power which adds about 15% to the cost.

If electric power is to be used, the prices of the above are about 5% higher.

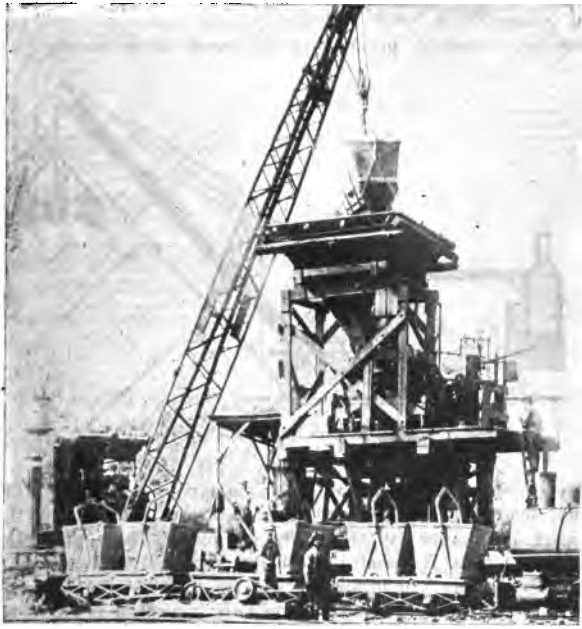


Fig. 208. Crane Hoisting Buckets of Concrete.

Electro Magnets. Steam turbine generating sets, complete with magnet, from $4,000 for 10 KW set with 55-inch magnet, such as is used on the larger cranes, to $2,500 for a 5 KW set with 36-inch magnet, as used on the smaller cranes.

A machine primarily designed as a steam shovel, but which

can be equipped with the locomotive crane boom and arranged to operate a clam shell bucket, costs as follows:

Standard type A, locomotive crane	cap. 3 tons, 26 ft. boom	$7,200
Standard type A, shovel	cap. ½ cu. yd.	7,200
Standard type B, locomotive crane	cap. 5 tons, 32 ft. boom	8,200
Standard type B, shovel	cap. ¾ cu. yd.	8,200

Approximate shipping weight of type A is 24,000 lb. and of type B is 40,000 lb. Prices f. o. b. Pennsylvania.

A tractor crane similar to the one shown in Fig. 209 has the following specifications. It consists of a stiff leg derrick with a counterweighted mast mounted on a steel car. It is operated by a steam-driven hoist and due to the counterweight no outriggers are required, permitting the boom to be swung through

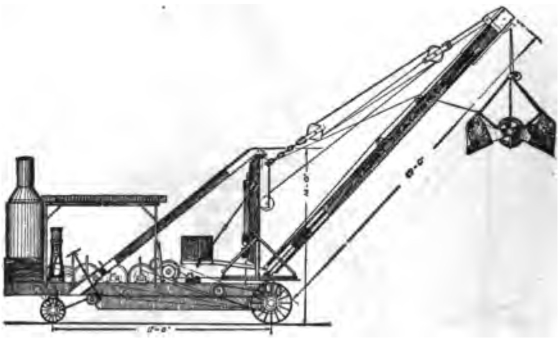


Fig. 209. Tractor Crane.

an arc of about 300 degrees. The capacity is rated as follows: a hook load of 5,500 lb.; a 1 yd. clam shell bucket with coal weighing 50 lb. per cu. ft.; a ¾ yd. bucket with material 100 lb. or less per cu. ft.; and a ½ yd. bucket with wet sand or other material weighing 120 lb. or less per cu. ft. The maximum reach is 20 ft. from center of mast. The hoisting speed is rated at 175 ft. per minute for bucket work and 100 ft. per minute for hook work. The travel speed on a 4% grade is 75 ft. per min. The approximate shipping weight is 25,000 lb. and the price is $6,500 with tractor wheels and $7,500 with caterpillar wheels.

A patented auto crane has the following specifications. Capacity as a derrick, 4,500 lb. at a 20 ft. radius. Maximum dead load capacity, 5,000 lb. Length of car body 17 ft. 10 inches, width 6 ft. 6 in. Length of boom 30 ft., weight without bucket

11 tons. Propelling speed 150 ft. per min. on hard level ground. This outfit may be had with either steam, gasoline or electric drive and costs with wheel traction $5,000 not including bucket. With caterpillar traction the cost is more. For car unloading a ¾ cu. yd. bucket is used and for excavating a ½ yd. bucket. The bucket costs about $700 extra. The approximate shipping weight of the outfit is 13 tons. This machine is illustrated by Fig. 210.

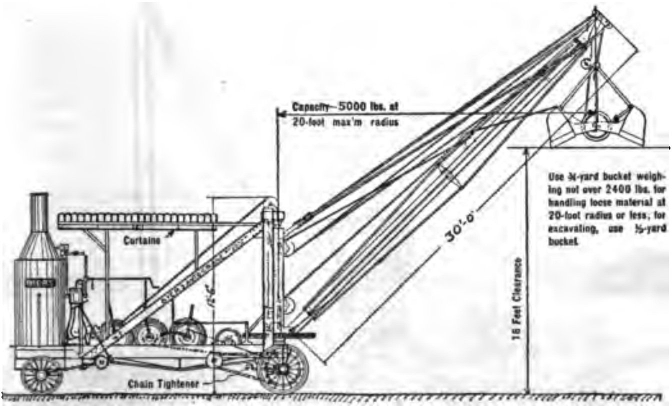


Fig. 210. Auto Crane.

A gasoline driven crane has the following specifications: multipedal traction, standard boom of 30 ft., capacities of from 4,500 lb. at a 30 ft. radius to 13,000 lb. at a 10 ft. radius. The traction speed is from ½ to 1¼ miles per hour.

This outfit weighs about 33,000 lb. and costs $9,600 f. o. b. Chicago.

Locomotive Crane Equipped with an Attachment for Pile Driving. A novel device for driving piles has been used on the Nickel Plate R. R. in its grade crossing elimination work in Cleveland. The contractor has fitted this crane with a simple and inexpensive attachment for driving the piles. The accompanying cut shows the crane with this special attachment driving piles for an elevated switch.

Two 25-ft. guides are hung from the end of the crane boom, being held by a bolt, and they are free to swing back and forth. When driving, the guides are held rigid by a brace fastened to the completed portion of the trestle. The piling is securely held in the guides by several cross braces on the back side, and on the

front side by an iron bar placed cross the two hooks at the bottom of the guides. The hammer is operated with a single hoisting rope, and hook, controlled by the operator of the crane. The trigger for releasing the hammer at the top, is a bolt, inserted in one of the guides. The crane hoists the piling up into the guides for driving, with the same hoisting rope that operates the hammer. While this is being done, the hammer is held at

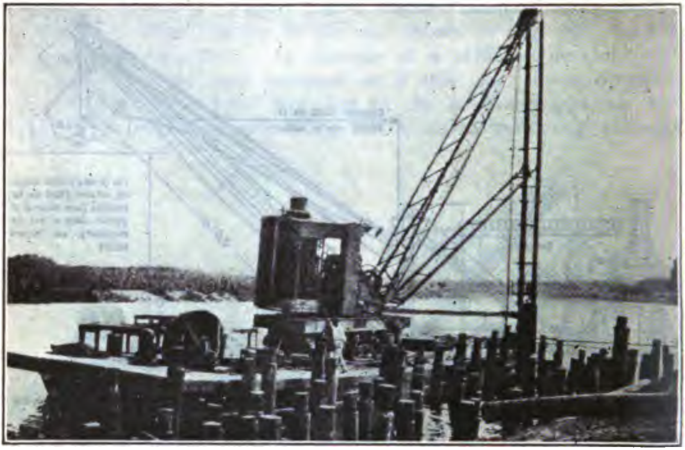


Fig. 211. Crane and Pile Driver Attachments Operating on a Barge.

the top of the guides with a bolt, placed through the guides by one of the workmen. The guides are equipped with a ladder as shown in the cut so that the workman can reach the top.

The railroad has used 40-ft. piles and has driven them 20 ft. into the ground, which consists of practically all shale. The contractor claims that he can drive four of these piles in less than an hour. The guides are easily and quickly attached to or removed from the locomotive crane.

SECTION 56

LOCOMOTIVES

The tractive force or drawbar pull of a locomotive is its pulling strength in pounds measured by a dynamometer. The larger the cylinders and the greater the steam pressure, the greater the tractive force; the larger the diameter of the driving wheels, the less the tractive force.

Let T represent the tractive force.
Let D represent the diameter of the cylinders in inches.
Let L represent the length of stroke of the pistons in inches.
Let 0.85 p represent 85% of the boiler pressure in pounds per square inch.
Let d represent diameter of the driving wheels in inches.

$$\text{Then } T = \frac{D^2 \times L \times 0.85\,p}{d}$$

Example: To find the tractive force of a locomotive with cylinders 10 in. in diameter by 16 in. stroke, 150 lb. boiler pressure, and driving wheels 33 in. in diameter:

$$T = \frac{10^2 \times 16 \times 0.85 \times 150}{33} = 6{,}182 \text{ lb.}$$

Mr. H. P. Gillette says: "It is very commonly stated that 20 lb. is the force required to pull a 2,000-lb. load over light rails. This may be so over carefully laid, clean track, with ties close-spaced and with car wheels well lubricated; but over the ordinary, rough, contractor's track 20 lb. is much too low an estimate.

"In the 'Coal and Metal Miners' Pocket Book' is a table giving actual results of traction tests, including several hundred separate tests under varying conditions. From these tables I have summarized the following:

	Per short ton
Pull to start mine cars (old style) loaded	90 lb.
Pull to start mine cars (new style) empty	80 lb.
Pull to keep up 4½-mile per hour speed (old style empty)	56 lb.
Pull to keep up 4½-mile per hour speed (old style full)	66 lb.
Pull to keep up 4½-mile per hour speed (new style empty)	30 lb.
Pull to keep up 4½-mile per hour speed (new style full)	38 lb.

"The foregoing was for trains of 1 to 4 cars, but with a train of 20 cars the pull was 46 lb. for old style cars and 26 lb. for new style cars per short ton on a level track. The mine cars used had a wheel base of 3½ ft.; they weighed 2,140 to 2,415 lb. empty and 7,885 to 9,000 lb. loaded. The diameter of the wheels was 16 in., and of axles 2⅛ in. for old style car to 2½ in. for new style car, with a steel journal 5¼ in. long, well lubricated in all cases, in fixed cast-iron boxes. The new style cars had better lubrication, the importance of which is well shown by the results of the tests. The track in the mine was level and in good condition. We know of no tests on car resistance of small cars that are as extensive and trustworthy as the foregoing."

Fig. 212. Saddle Tank Locomotive 4-Coupled.

Based upon these data, and upon the assumption that the resistance to traction is 40 lb., per short ton, an 8-ton dinkey is capable of hauling the following loads, including the weight of the cars:

Level track	70
1% grade	46
2% grade	33
3% grade	26
4% grade	21
5% grade	17
6% grade	14
8% grade	10

Note: On a poor track not even as great loads as the above can be hauled.

Due to the accidents that frequently occur from the breaking in two of trains on steep grades, and from the running away of

engines, it is advisable to avoid using grades of more than 6%.

When heavily loaded, a dinkey travels 5 miles per hour on a straight track; but when lightly loaded, or on a down grade, it may run 9 miles an hour.

Four-Coupled Tank Locomotives of one make are as follows:

Cylinders Dia. stroke inches	Gauge	Total weight	Hauling capacity on level, tons	Price f. o. b. works
5 by 10	2′	11,700	175	$5,000
7 by 12	3′	17,200	365	5,500
8 by 14	3′	21,000	515	6,200
10 by 16	3′	35,700	855	7,200
11 by 16	3′	39,800	1000	8,700

The hauling capacity on a ½% grade is about one-half of that on the level. On a 6% grade it is about 5% of the hauling capacity on the level.

Six-Coupled Locomotive for contracting service is built in standard gauge. The cylinders are 16 by 24 inches, boiler pressure

Fig. 213. 6-Coupled Locomotive.

180 lb., the weight on the driving wheels is 86,300 lb., weight with tender 156,000 lb. The hauling capacity in tons, exclusive of the engine and tender, is 2,035 on the level. The hauling capacity on a ½% grade is 960 tons; 1% grade, 590 tons; 2%, 310 tons; 3%, 195 tons. This locomotive costs about $21,200 f. o. b. works.

Locomotives of another make cost as follows:

Four Coupled

Saddle or side tanks, fuel box in cab.

Cylinders Dia. stroke	Gauge, in. and over	Tract. effort in pounds	Weight in pounds	Price f. o. b. factory
6 by 10	20	2,445	15,000	$4,500
8 by 12	20	4,350	21,000	5,500
10 by 14	30	6,770	32,000	6,500
11 by 16	30	8,435	42,000	7,500
12 by 16	30	10,100	50,000	8,500

with rear fuel bunker

12 by 18	std	11,000	56,000	$ 9,500
14 by 20	std	14,900	80,000	12,000
16 by 24	std	21,400	98,000	16,000

The steam pressure for the above locomotives is from 150 to 180 lb. per sq. in.

Gear Drive Locomotives especially designed for construction work, are as follows:

SIX WHEEL

Cylinders Dia. stroke	Gauge in inches	Tract. effort in pounds	Weight in lb.	Price f. o. b. factory
6½ by 8	24 to 36	4,225	14,500	$ 5,500
8 by 10	24 to 36	6,700	22,000	6,500
10 by 14	24 to 36	11,600	42,000	9,000
11½ by 14	24 to 36	16,300	60,000	11,000

FOUR WHEEL

5½ by 8	24 to 36	3,000	10.500	$ 4,800
7 by 10	24 to 36	5,120	19,000	5,500
8½ by 12	24 to 36	7,400	26,000	6,700
9½ by 14	24 to 36	10,500	36,000	7,800
11 by 14	24 to 36	14,900	50,000	9,500

The boiler pressure of the above is 160 lb. for the smaller sizes and 170 lb. for the larger. The foregoing prices are all f. o. b. factory in Iowa.

Gasoline Locomotive. A gasoline locomotive similar to that shown in Fig. 214 is built in two sizes. The 3 ton size has the following specifications: Gauge, from 18 to 56½ inches; speed, up to 10 miles per hr.; draw bar pull, 1,200 lb. at 5 miles per hr.; 600 lb. at 10 miles per hr.; cost, f. o. b. Ohio, $2,200.

The 6 ton size has the following specifications: Gauge from 24 to 56½ inches; speed, up to 10 miles per hr.; draw bar pull, 2,400 lb. at 5 miles per hr.; 1,200 lb. at 10 miles per hr.; cost, $3,650 f. o. b. Ohio.

Mr. Andrew Harper says that the life of a dinkey locomotive used on construction work is about 20 years. During that time it will need 2 or 3 sets of driving tires, and brasses.

Upon investigation of a very large number of locomotives upon the Great Northern, Northern Pacific and other railroads made by Mr. Gillette for a railway commission, the average life of a locomotive in railroad service is not far from 25 years, so that a fair average for depreciation may be 4% if figured on the straight line formula. This does not represent the life of the different parts of the engine however.

On the Southern Pacific R. R. in six years there was an average

of 49 locomotives out of 1,540 vacated per year or 3.2 per cent, which would establish the life of these locomotives at 31 years.

From July, 1907, to June, 1908, the cost of repairing locomotives for the Isthmian Canal Commission averaged about $81.45 per month per engine valued at about $7,500, or at a rate of 13% per year.

Mr. R. Price Williams contributed a paper on the maintenance

Fig. 214. Gasoline Locomotive.

and renewal of average railway freight locomotives for the Institute of Civil Engineers of Great Britain, from which have been abstracted the following data on the life of various parts of locomotives:

Life in train miles	Life in years	
10,000	½	India rubber pipe.
80,000	4	Painting.
100,000	5	Brass tubes, steel ferrules.
120,000	6	Crank axles, moulds, etc.
	7	Tires, pressure gauges, buffer planks, spindles, brass guards, wash out plugs, etc.
	10	Boiler, journal boxes and caps, brasses, brass valves and syphons, firebox shell ends, tube plate and back firebox, copper recess plates, etc.
	15	Motion cylinders, reversing catchslide blocks, blast pipe, ash pan, outside and inside springs, spring links, spring pins, etc.
	17	Lubrica or, shackle, buffer plank, chains.
	20	Clock boxes, balls and clocks, feed pipes, smoke-box door, etc.

30	Plain axles, wheels, outside cranks, balance weights, slide bar brackets, slide bars, distance blocks, eccentric rods and straps, reversing gear lever and bracket, reversing rod shaft, quadrant and collar, connection rods and straps, bolts, framing, etc.
	TENDER
½	Brake blocks, hose packings, etc.
3	Painting, tires, bolts and nuts for tender.
5	Oak plank.

"The standard value of an engine" (on the parabolic assumption) = ⅔ net cost, and the normal dilapidation ⅓ net cost.

The life of locomotive tubes is a very important part of this question.

Mr. W. Garstang is authority for the statement that on the Big Four the average life of charcoal iron tubes was 75,000 miles and on freight service 58,000 miles taken from engines with shallow fireboxes. When the fireboxes are deep the tubes accomplish 15% more mileage. The data were obtained from No. 11 tubes weighing 2¾ lb. per foot and it was the practice to continue to piece the best tubes until the weight was reduced 1.4 lb. The average tube was pieced about 10 times before being condemned.

Mr. B. Haskell, of the Pere Marquette, believes that the life of locomotive tubes varies from 5 to 9 years, depending upon the quality of water used. The tubes worked an average of 15 months in service before being removed.

C. E. Queen's experience was to the effect that with alkali and incrusting solids in the water the tubes have failed in as short a time as 3 months, while with no scale and good water the tubes will last as long as 15 years.

Mr. D. Van Alstyne, of the Chicago Great Western, says that the average run on the road was 15 months, with average life of 7 to 8 years, steel tubes being limited to 6 months' service in one engine. Life of the deep firebox is longer than that of the shallow one.

Mr. Thos. Paxton, of the A., T. & S. F., does not know of a single feature of locomotive maintenance subject to wider variation than tubes. On the Middle Western division of that road, in freight service, it was difficult to get 18,000 miles per tube, while on the west end of the Chicago division 80,000 miles was obtained.

In the year 1907 the cost of maintenance of engines on several representative American railroads was as follows:

	Maintenance of locomotive per year	Maintenance of locomotive per train mile	Maintenance of loco. per ton of fuel burned
Atchison	$2,875	12.50c	1.9c
Chicago & Alton ..	2,599	9.85	1.16
D., L. & W........	1,460	8.16	.731

These show an average of a little over $2,000 per locomotive per year, which is probably not far from 20% of the original cost of each engine.

Locomotive Repair Costs, Panama. The cost of repairs to locomotives, 286 in service, at Panama for the year ending June 30, 1910, was as follows per locomotive:

Item	Cost
Labor	$ 818
Material	316
Total	$1,134

The total cost of repairs during the 6 months ending June 30, 1910, for 31,955 days' service was an average of $6.94 per locomotive per day.

The following is a detailed statement of the cost of repairs to engine No. 7, Dansville & Mt. Morris R. R., under the charge of the author. This engine had been operating for over a year with nothing but minor repairs and was no longer in fit condition for regular operation. These repairs include a pretty general overhauling and are about what would be necessary, aside from minor work that can be done by a roundhouse man, to keep it in fair condition for one year with a performance of about 15,000 miles. This is on a small railroad in the central part of New York. The tractive power of this engine was 11,100, the total weight 43 tons, and the weight on the drivers 29 tons.

4	New figd. steel tires 57⅜-in. W. C. 5½ x 3½, 4,496 lb. @ 2¾ cents	$123.64
110	New steel tubes 2"x 10'-6½", @ .10 ⅛-ft.	117.44
54	New safe ends for tubes, @ .08	4.32
170	New copper ferrules ¾ x 2 x 2⅛", 10 lb. @ .22	3.96
176	New copper ferrules ¾ x 1⅞ x 2⁵⁄₃₂, 35 lb. @ .23½	8.20
42	New stay bolts, 1⁵⁄₁₆ x 7", @ .08	3.36
8	New stay bolts, 1x 7", @ .09	.72
5	New stay bolts 1⁵⁄₁₆" iron, 10 lb. @ .05¹⁄₁₀	.51
13	New ³⁄₁₆" twist drills (broken drilling stay bolt holes)	1.30
2	New sheets ³⁄₁₆" tank steel (tank bottom), 820 lb. @ 1.96	16.17
1	New sheet ³⁄₁₆" tank, 52 lb. @ 2.20	1.14
2	New sheets C. R. jacket steel No. 22 x 28 x 72", 55 lb. @ 2.80	1.55
1	New C. I. driving box shoe and wedge, 60 lb. @ .02½.	1.50
	Babbitt metal for crossheads, 7½ lb. @ .22	1.65
	Wrought iron, 72 lb. @ .02¼	1.62
	1" gas pipe, 6½ ft.	.21
1	Air hose complete with couplings	2.00
	2½" tank hose, 3 ft. @ .56	1.68
1	1" brass plug cock	.60
18	½ x 2" bolts with nuts and washers, .06	1.08
32	⅛–1⅛" bolts with nuts and washers, .01½	.48
21	⅜–1" bolts with nuts and washers, .01½	.32
2	¾ x 15" bolts with nuts and washers, .07	.14
4	¾ x 9" bolts with nuts and washers, .05	.20
6	¾" nuts	.13

6	¾" washers	.03
	Nails 20d., 1 lb. .03, 10d., dp 1 lb. .03	.06
	Rivets, ⅜ x ¾, 9 lb.	.66
	Rivets, ⅜ x ⅞, 24 lb.	1.43
	Rivets, ⅜ x 1, 2 lb	.10
	Rivets, ⅜ x 1½, 2 lb.	.10
2	16" square bastard files, @ .16	.32
1	16" half round bastard file	.18
6	Candles, @ .02½	.15
1	Hacksaw blade	.10
	Coke, 60 lb.	.45
	½ Cord wood (heating tires)	1.00
	Wool waste, 12 lb. @ .04½	.54
	Tar paper, 38 ft.	.13
1	Ball lamp wick	.09
1	Sledge handle	.12
31	Sheets sand paper	.22
3	Sheets emery cloth	.07
	Powdered emery, 1½ lb.	.08
4	Pieces finished pine 2 x 6 x 19 ft.	2.16
6	Pieces finished pine 2 x 8 x 19 ft.	4.44
3	Pieces finished pine 1¾ x 10 x 9 ft.	1.17
1	Piece finished oak 2 x 9 x 13 ft.	1.30
1	Piece finished oak 2 x 8 x 10 ft.	.83
	Asphaltum, 1½ g.	.32
	Gloss black, ½ g.	.23
	Drop black, 8 lb.	1.96
	Cab green, ½ g.	1.03
	Turpentine, 1 g.	.80
	Linseed oil, ¼ g.	.12
	White lead, 2 lb.	.17
	Red lead, 2 lb.	.24
	Japan dryer, ¼ g.	.23
	Varnish, 1½ g.	3.06
	Filler, 5 lb	.50
	Russia jacket finish, 1 g.	2.50
	Black engine finish, 1½ g.	3.03
	Aluminum leaf	.20
	Cylinder oil, 1 g.	.41
	Engine oil, 2½ g.	.45
	Black oil, 1 g.	.15
	Valve oil, 1 g.	.14
	Kerosene, 4½ g.	.51
	Benzine, 4½ g.	.70
	R. R. ticket for messenger	7.00
	Total	$333.40

Applied labor, 1,540½ hours	$347.67	
Overhead 80% labor	278.14	
		625.81
		$959.21
10%		95.92
		$1,055.13
Credit for scrap, as follows:		
4 Steel tires, 2,450 lb. @ 12.50 C. T.	$13.67	
Tube and tube ends, 404 lb. @ ½-cent lb.	2.02	
92 Second-hand tubes, 2" x 10'–0", @ .10½	96.60	
Copper ferrules, 8 lb. @ .10½ lb.	.84	
Stay bolts, 28 lb. @ ½-cent lb.	.14	
Tank steel, 674 lb @ ½-cent lb.	3.37	
C. I. shoe and wedge, 52 lb. at ½-cent lb.	.26	
Brass plug cock, 1 lb.	.07	
		116.97
		$937.50

This included the following items of repair:

Examine and repair brasses.
Two second-hand wheel centers.
New 3½-in. tires.
Examine crank pins.
Take up side motion in driving boxes.
Turn engine truck tires.
Examine driving box brasses.
Examine cylinders.
Examine valves.
Examine front end.
New studs for front door ring.
Cross head gibs babbitted.
Remove flues and copper both ends when replaced.
Examine stay bolts and drill tell-tale holes.
Examine boiler as per form No. 2, Public Service Com. and examine all corners of mud ring for leaks.
Examine flue sheet.
Test steam gauge and pops.
Take out ¾-in. air pump dry pipe and replace with 1-in.
Examine tender bottom, probably renew.
Stay sheets in tank gone, replaced.

SECTION 57

MACHINE SHOP OUTFIT

Lathes cost from $200 for the small sizes to $2000 to the larger sizes depending on the type. A 24-inch swing 12 ft. bed engine lathe weighs about 5,500 lb. A second-hand machine of this type can be bought for about $500.

An upright drill, 20-in. weighs 700 lb. and costs $200.

Fig. 215. 20-in. Upright Drill.

A bolt cutter to thread bolts or tap nuts ⅜ in. to 1½ in., right or left hand, weighs 1,200 lb. This machine can be bought second-hand for about $400.

A single end punch or shear weighs about 4,500 lb. and will punch a 1 in. hole through ½ inch plate or will shear a 4 by ⅛

inch bar. A second-hand one will cost about $550 and a new one $950.

Grindstone, machinist's: 30-in., heavy, mounted on an iron frame, with shield and water bucket, weighs about 1,500 lb. and costs new about $100.

Portable Shops as Developed by the Engineer Department of the U. S. Army. 1. Early in 1917, the advisability of supplying

Fig. 216. Bolt Cutter.

Engineer troops in France with portable shops was considered by the Engineer Department. Designs were soon drawn up and orders placed.

2. The units decided upon form a train, consisting of a portable machine shop, carpenter shop, blacksmith and tin shop, and a portable supply or material unit. Each consists of a special body, mounted upon a 5½-ton truck. The train can be operated as a whole, or each of the units can be operated independently. The shops were designed for the repair of the equipment of practically all classes of Engineer troops. This includes equipment for Roadmaking, Forestry, Quarry operations, Pontoon and other Bridge activities, Water Supply, General Construction and Railroad Construction.

3. The most interesting unit of the four is the Machine Shop, the equipment of which is outlined below:

A steel body with solid wood floor, supported from proper sills, was arranged to be easily mountable, or demountable, at will, yet secure when under severe running conditions.

The floor spaced body closed is 6 ft. 9 in. x 13 ft. While with the platform sides swung down to floor level, the floor space becomes 11 ft. 3 in. wide by 15 ft. 3 in. long. The head room is approximately 7 ft.

Suitable canvas covers provide shelter for the top and sides not covered by the folding up of the platform extensions.

Within the shop the equipment is arranged to give fair working room about each tool and bench, and, at the same time, all tools or equipment may be removed for temporary use outside.

Fig. 217. Engineer Field Machine Shop.

The principal tools are a 14-in. LeBlond lathe with 5 ft. bed, driven by a 2 hp. 110 volt motor, the lathe has the usual complement of attachments and controls. An 18-in. drill press — motor driven and capable of drilling with a ⅝-in. drill in steel; a 2-wheel 10-in. x 1-in.— 2,000 R.P.M motor driven grinder; a work bench with vise and 6 drawers — the top made of 1¾-in. oak being 2 ft. 3 in. x 5 ft. 6 in. long; an electric portable drill, good for 1-in. holes in steel; 2 electric portable hammers, 2 complete oxyacetylene welding and cutting outfits; a reasonable complement of bench and hand tools, abrasives, drills, supplies, jacks, measuring tools. These latter arranged for with proper fastenings in place.

The shop is electric lighted, the wiring being carried in regula-

tion conduit, and with suitable outlets for cutting in or out, to or from the engines, tools or other units outside of the shop.

A suitable corner crane with a 1,000 lb. Yale Triplex Hoist serves the purpose of lifting heavy articles onto or off of the floor and ground. The power plant is an independent unit, direct connected, 4 cylinder, 1,000 R.P.M. Winton Gasoline Engine, and a 5 K. W. Generator complete with switchboard, tanks and cooling system, arranged for power and lighting circuits.

The cost of the complete outfit — truck, body, and complements of tools at war prices was less than $8,500. The entire train complete cost $27,800. (The body and tools weigh around 11,000 lb.) A number of the complete trains were used in France, others on this side at the training camps and schools for Engineer Troops, giving excellent satisfaction and receiving favorable comment from those who used them extensively.

The speed of this machine on ordinary roads is about 6 miles per hour and on good roads is about 10 miles per hour. The time to set up ready for work under ordinary conditions is generally 10 minutes. It would be more for accurate work.

It is believed that the outfit should have a place in the equipment of any contractor who handles projects of reasonable size. The investment is not large, and the service capable of being rendered on the spot, in quick order, would save much time of delivery of parts for repairs usually sent to a village shop. The body could be demounted at the site and the truck used for other work in the interval. Interest on the investment added to a 12% depreciation amounts to about $1,200, which, for 300 working days, makes a cost of $4.00 per day added to supplies needed. On this basis, it is not hard to figure the volume of yearly business which would warrant the maintenance of such an outfit.

The author is indebted to Major Gen. Black, Corp. of Engineers, U. S. A. for the above notes, and for the photograph of the apparatus.

Shop Boats for Keeping Plant in Repair. Major H. Burgess, in *Professional Memoirs* for December, 1915, has written the following: A machine shop boat and carpenter shop boat not only keep the plant in repair but also manufacture small repair parts. The machine-shop boat carries a small ice plant and a blacksmith shop. The equipment at Kogers Island includes two dipper dredges with 1½-yd. buckets, one towboat and one small steam tender, three derrick-boats equipped with 1-yd. orange-peel buckets, two full-sized drill rafts and tenders, one half-sized drill raft and small tender, and a number of scows. barges, quarter-boats, launches and skiffs.

The layout of the floating carpenter shop is shown by the lower sketch. A shop building 106 x 24 ft. in plan by 11 ft. high was constructed on a decked barge and equipped with a wood-worker, a lathe, a bandsaw with adjustable table and a grindstone, all driven by a 10-hp. gasoline engine. There is also an electric borer. At one end are two derricks for handling heavy timbers, small launches and skiffs, one of which is rigged with a double and triple block, the other with a differential chainblock. The derricks place heavy pieces on roller cars, which can be moved readily about the shop.

The floor space is sufficient for simultaneously working on two or three of the longest and largest boats used in the fleet, for building at one time several skiffs or for repairing a launch at the same time that skiffs are being built. When the demand for carpenter work is light, the floor space can be utilized for storage.

The barge cost $4,375 to build and $2,000 to equip with cabin and machines.

The hull of the machine-shop boat is exactly like that of the carpenter-shop boat. Its total cost equipped was about $11,520. The steam for operating engines, pumps and generator set is supplied by a 60-hp. boiler.

Shop Cost and Purchase Price of Dredge Parts

Dipper dredge parts	Shop cost	Cost from dealer
Dipper shaft, weight 50 lb.	$ 2.25	$ 5.00
U bolt, weight 125 lb.	6.50	13.50
Latch keeper, weight 60 lb.	4.75	9.80
Latch bar, weight 36 lb.	2.80	5.94
Bottom band, weight 200 lb.	8.50	13.35
Back brace, weight 108 lb.	4.60	8.69
Door plate, weight 345 lb.	14.60	18.98

The blacksmith shop occupies the full width of the cabin, is 37 ft. long and contains two forges, two anvils, one power blower and the usual equipment of tools, quenching tanks, etc. The floor is covered with a 2-in. carpet of mixed coal dust and cinders, which is kept damp for fire protection. There are three shifts of one man each. Comparatively heavy work can be done here; for example, a broken 5-in. wheel shaft of one of the tow-boats was successfully welded and the wheel again in service in 48 hr. An important duty of the smiths is to keep ready for use an extra bucket of each size and shape for installation on any dredge or derrick boat.

In the machine-shop, power is furnished by a 15-hp. Dayton center-crank vertical engine. The general layout of the shaft-

ing is about what is found in a small machine shop on land. The principal work of the mechanics is keeping ready for service the full number of drills needed for one half-sized and four full-sized rafts — that is, about 54 drills. The service of the drills, especially in the flint, is severe, and four or five are broken a day.

The actual cost of making certain dredge parts at the shop

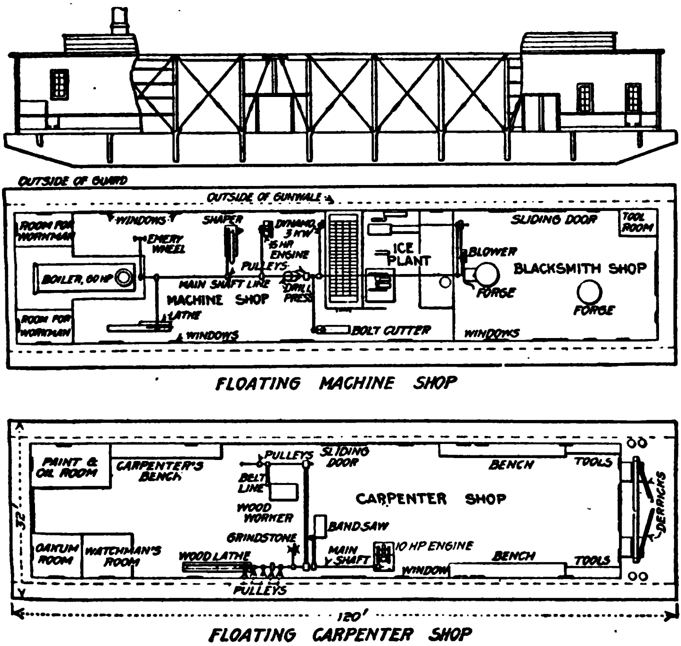


Fig. 218. Layout of Two Federal Shop Boats — Machine and Carpenter.

and the purchase price from dealers, according to the experience of the past two years, are tabulated above. To the shop cost should be added about 10% to cover depreciation, overhead charges, and other elements of total cost.

Cost of Electric Power for Operating Machine Shop. The following table is taken from bulletin No. 38 of the Iowa State College Engineering Experiment Station.

Machine	Rated hp. of motor	Cost per hour to operate at 10 ct. per kw. hr.
16-inch drill press	2	$0.075
12-inch cut off saw	3	.10
16-inch swing cut off saw	3	.10
8 inch self feed cut off saw	3	.10
8-inch friction feed saw	3	.10
Band saw	3	.125
12-inch self feed rip saw	5	.20
24-in. machine lathe	5	.20
Milling machine	5	.20
42-inch planer	10	.20
52-inch boring mill	10	.30
8-foot boring mill	20	.60

SECTION 58

MIXERS

Concrete mixers are usually divided into three classes: (1) Batch mixers, (2) Continuous mixers, and (3) Gravity mixers. In batch mixers the ingredients of the concrete in a proper amount or "batch" are placed in the machine, mixed, and discharged before another batch is placed in the mixer. In continuous mixing, the materials are allowed to enter the machine and the concrete to discharge continuously. Gravity mixers consist of especially constructed hoppers, troughs, or tubes so arranged that the ingredients flowing through them under the influence of gravity are mixed together into concrete.

1. Batch mixers are commonly of two types: One, that in which the drum is tilted in order to discharge the mixture; the other, that in which the drum is not tilted, but the concrete on being raised in the mixer by the mixing paddles drops on the inner end of a discharge chute which conveys it to wheelbarrows or other placing devices.

The following prices, etc., are those of a tilting mixer in which the drum, supported on horizontal axes, is tilted in order to discharge the concrete. The drum of this machine is formed of two truncated cones with their large ends joined and the concrete is mixed by means of steel plate deflectors:

Description	No. 1	No. 2	No. 3
Listed capacity per batch mixed concrete, cu. ft.	2½	4½	8
Mixer on skids, hand or belt power, wt. 425 lb.	$ 85	...	....
Mixer on skids, tight and loose pulley, wt. 655 lb.	...	$135	....
Mixer on skids, tight and loose pulley, 1,175 lb.	...	...	$ 300
Mixer mounted on hand portable trucks, 475 lb.	95	...	....
Mixer on extended trucks for engine, 950 lb.	...	195	....
Mixer on trucks with 2 hp. engine, 975 lb.	240	...	....
Mixer on trucks, 3 hp. engine, 1,650 lb.	...	385	....
Mixer on trucks, 3 hp. engine and hoist, 1,975 lb.	...	435	....
Mixer on trucks, 3 hp. engine and loader, 2,450 lb.	...	565	....
Mixer, trucks, 5 hp. engine, loader, hoist, tank, 3,175 lb.	...	790	....
Mixer, trucks, 5 hp. engine, loader, water tank and power dump, weight 3,925 lb.	...	...	1,020
Mixer, trucks, 8 hp. engine, loader, hoist, water tank and power dump, weight 4,840 lb.	...	...	1,295

Placing Plant, including mixer, designed for eliminating as much labor as possible in the placing of concrete in forms on

such work as foundations, piers, abutments, slabs, floors, roofs, arches, bridges, etc., consists of an inclined track made up in five sections, each 10 ft. long, skip car, hopper at end on track to receive batch, self-supporting spouts reaching 25 ft. Additional spout and track may be had if desired. The mixer is complete with engine and drum for operating the hoist, power loader and tank. The outfit comes with two sizes of mixers; with mixer of 8 cu. ft. mixed concrete per batch, the complete weight is 7,690 lb., price $1,835. With mixer of 4½ cu. ft. capacity, weight 5,885 lb., price $1,270.

Fig. 219. Mixer Capacity 3 to 4 cu. ft. Unmixed Materials, or About 2½ cu. ft. Mixed Concrete.

In the installation of this equipment, the manufacturer suggests a rise of not more than 4 ft. per section. With regular outfit of 5 sections the top of the last section would be 20 ft. from the ground, 10 ft. of this is needed for the fall of the spouts which leaves 10 ft. for the height of the forms. If higher forms are used it is necessary to use more sections. Extra sections of 10 ft. weigh 200 lb. and cost $55.

A paver of the type given in the table above is made in one size. It has a capacity of 8 cu. ft. of mixed concrete per batch. It is equipped with open end bucket, water tank, power dis-

charge, platform for operator, traction forward and reverse, differential gears, knuckle joint steering, one-man control, spout, 8 hp. engine, complete. The weight of this machine is 6,750 lb. and the price is $2,105.

The prices of all the foregoing machines are f. o. b. factory in Ohio. The general type of the mixer is as follows. The drum

Fig. 220. Mixer 8 cu. ft. per Batch, with Power Loader.

has a single opening, of the tilting type, the manufacturers claiming the following points in superiority to the non-tilting type: larger capacity for its size; requires less power to operate; produces a better mix in less time; a larger opening to load; discharges more rapidly and stays clean. The drum consists of a semi-steel bowl which forms the lower half of the drum, the steel cone forming the upper.

Fig. 221. 8 cu. ft. per Batch Paver.

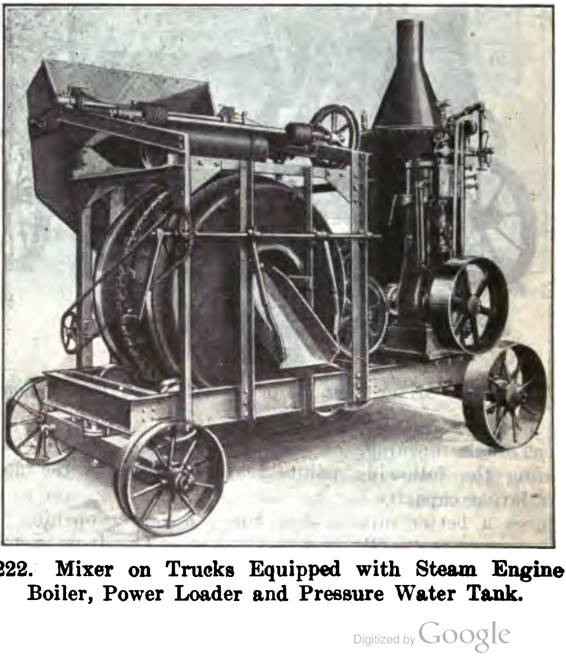


Fig. 222. Mixer on Trucks Equipped with Steam Engine and Boiler, Power Loader and Pressure Water Tank.

The bowl has two flat pieces on opposite sides which help to bring material from the bottom forward, the cone part carrying it back.

Mixers of the non-tilting type, of one make, are priced as follows:

Size of batch in cu. ft.	5	7	10	15
Capacity in cu. yd. per hour	7½	9¼	15	22
Horse power	3–4	3–5	5–6	8–10
Shipping weight without power on trucks	1,600	2,400	3,400	4,900
Shipping weight with steam engine and boiler	....	....	4,400	5,600
Shipping weight with gasoline engine	2,000	3,000	4,200	5,500
Shipping weight with electric motor	1,750	2,600	3,800	5,100
Price without power on trucks	$ 270	$ 370	$ 565	$ 905
Price with steam plant	....	....	1,125	1,750
Price with gasoline engine	415	595	805	1,325
Price with electric motor, average	500	650	865	1,375
Shipping weight of power loader and tank	400	860	1,340	1,500
Price extra for power loader and tank	$ 190	$ 190	$ 380	$ 390

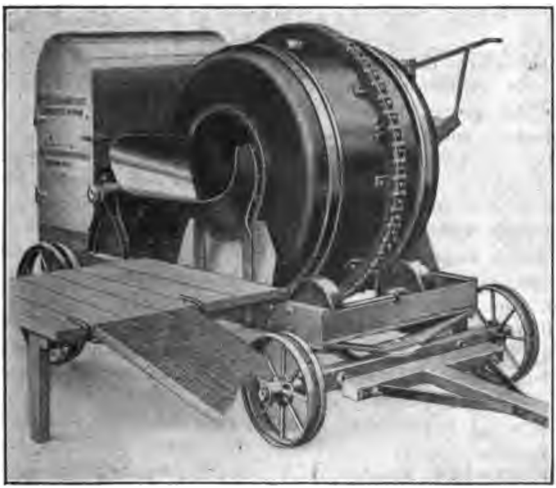


Fig. 223. Low Charging Mixer.

Another make costs as follows:

Capacity per batch in cu. ft. loose material	5	7	10	21
Capacity per batch in cu. ft. wet material	3½	5	7	14
Horse power	2½	4½	6	10
Horse power with power loader	3	5	6	10
Shipping weight without power on trucks	1700			
Shipping weight with steam engine and boiler				
Shipping weight with gasoline engine	2400	3400	3500	
Price without power on trucks	$ 345	$ 475	$ 565	$1325

Price with steam plant				2200
Price with gasoline engine	475	600	795	1975
Price extra for power loader	50	60	75	250
Price extra for water tank	35	50	50	75
Price extra for platform	25	25	25	

Batch mixers of another make, complete on trucks with gasoline engines without hopper, tanks, etc., are priced as follows:

Rated capacity per hour, cu. yd.	Weight in lb.	Price f. o. b. Milwaukee
6	2,700	$ 600
10	4,300	850
26	10,800	2150

With steam engine and boiler complete.

40	13,200	2700
50	14,300	3600
80	19,000	4500

In the above the weight and price for the 80 yd. size are for the outfit with steam engine and do not include the boiler.

For the above mixers there is a wide variety of additional attachments and space does not permit them to be listed in detail.

Extra equipment for the 6 yd. machine: batch hopper $60, water tank $60. 10 yd. size: batch hopper $75, water tank $85, power loader with tank $250. 26 yd. size: batch hopper $150, water tank $160, pivoted power loader and tank $625. 40 yd. size; batch hopper $180, water tank $170, pivoted power loader and tank $750. 50 yd. size: batch hopper $250, water tank $200. 80 yd. size: batch hopper $500, water tank $350.

A Concrete Mixer Heating Attachment consists of a tank containing oil under pressure that is forced through a burner inserted through the hollow trunnion of the mixer. The flame heats the revolving aggregate.

This outfit is regularly made in two sizes. The smaller is for use on mixers up to ½ yd. size. It consists of an oil tank with 12 gal. capacity, fitted with a powerful hand pump and gauge, burner complete, and one length of hose. It consumes 2 gal. of kerosene per hour, weighs approximately 160 lb. for shipment and costs $110 f. o. b. factory.

The larger size is adapted for use on a mixer up to ¾ yd. capacity. It consumes 2½ to 3 gal. per hr., weighs approximately 175 lb. for shipment, and costs $125 f. o. b. factory.

Mortar Mixer similar to the one shown in Fig. 225 is operated by a 4 hp. gasoline engine, rated at a capacity of material enough for 25 masons, weighs 1,500 lb. on trucks and costs $445 f. o. b. factory.

Grout Mixer and Placer. The machine illustrated in Fig. 226 is designed for mixing and placing grout under pressure by means of compressed air. It is used to seal the fissures, rifts, etc., in tunnel work and to check the flow of water; to close and eliminate voids where absolutely water tight work is required; to repair washouts under dams, walls, foundations, etc.; to solidify bad rock foundations, back fills, etc.

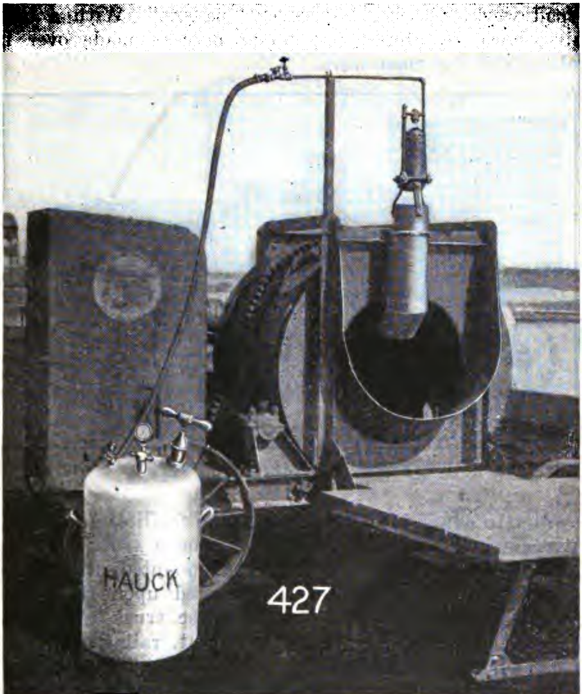


Fig. 224 Concrete Mixer Heating Attachment.

The size of batch is two sacks of cement and 2 cu. ft. of sand and whatever water may be required. Under ordinary conditions and when working under a head of 175 ft. or less, the batches placed per hour will average about forty. The air consumption per batch is approximately 250 ft. of free air per min. at the required pressure.

This machine comes in three types: the standard type operates at a pressure up to 150 lb.; the high pressure up to 300 lb.; and the extra high pressure up to 600 lb.

This machine is rented by the manufacturer at from $100 to $150 per month according to the type.

Adapting a Concrete Mixer to Road Work. The great development of the last few years in the use of concrete for road building has brought out many concrete mixers especially designed for road work — paving mixers or "pavers." With a little ingenuity, however, almost any mixer may be made over into a traveling unit for road work.

Fig. 225. Mortar Mixer.

In order to adapt it to road use and to facilitate quick moving, the expedient of mounting the mixer upon a truck was resorted to. The boiler of the machine was dismounted, this preserving the balance of the apparatus as mounted upon the truck and reducing the dead-load to be moved. The truck ran upon railway tracks built in 8-ft. sections, the 8-ft. rails being bolted to 3-in. flat planks and moved as one unit. The units were bolted together with fishplates as the truck was moved from one section to another. Motive power was furnished by a tandem steam roller, not only supplying the steam for the mixer engine but also acting as a tractor in moving the plant.

With the above arrangement on an average 300 lin. ft. of concrete pavement per day were laid, 18 ft. wide, with average depth of concrete of 6¼ in.

Traveling Bin for Charging Mixer. The following description of a bin appeared in the *Engineering News Record,* Feb. 5, 1920.

A mixer charging machine, which comprises storage bins, a measuring cylinder and a track incline, all mounted on wheels, reduced the cost of handling materials to the mixer on two Wayne County, Michigan, concrete roads built in 1919. The structure is steel with the bins and measuring device at the forward end and the track incline arrangement shown by the accompanying view. The capacity is 8 cu. yd. of stone, sand and cement. Cars of stone and sand arriving at the top are discharged into the bins and then returned to the surface tracks. Cars carrying

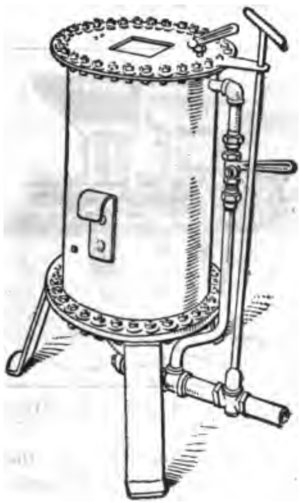


Fig. 226. Grout Mixer and Placer.

cement in bags are held at the top while the bags are untied as needed and emptied through a hopper and chute into the mixer charging hopper which, when lowered, extends under the overhanging platform on top of the bins.

Two 24-in. gage industrial tracks spaced 10 ft. apart on centers on the subgrade carry the apparatus. These tracks connect by switches with the industrial track on the shoulder of the road. A stiff coupling connects the structure with the mixer so that when the mixer moves ahead it pushes the bins along.

Continuous Mixers. A continuous mixer, of one make, illustrated by Fig. 227 costs as follows:

Capacity in cu. yd. per hr.	hp.	Weight in lb.	Price f. o. b. factory
4 to 5	2½	2,000	$405
5 to 8	3½	2,300	495
12 to 18	4½	3,200	645
20 to 35	6	4.700	880

The above prices are for mixers with battery ignition. For High Tension Magneto add $35. All the above are mounted on steel wheels.

A mixer similar to the above fitted with pulley for belt drive, rated at from 6 to 10 cu. yd. per hr., is mounted on skids and weighs 1,200 lb. The price is $196.

Fig. 227. Continuous Mixer.

A mortar mixer of the same make as the above, is rated to supply from 35 to 75 masons. Fitted with a 4½ hp. gasoline engine, it weighs 2,450 lb. and costs $430. With high tension magneto, $35 extra. This machine is mounted on trucks with steel wheels.

All the above mixers may also be driven by electric motors, the 12 to 18 and 20 to 35 cu. yd. sizes may also be had with steam engines and boilers.

Comparison of Rented and Owned Concete Mixers. From *Engineering Record,* New York. The figures in the accompanying tables have been compiled from the records of the Aberthaw Construction Company, of Boston, who ran a ledger account for each mixer. The oldest mixer is nearly seven years old. The original cost, repairs, and other expenditures are charged against the machine and it is credited with so much per day for the elapsed time it is on a job. This rental credit is based as nearly as pos-

sible on what it would cost to rent this plant instead of buying it outright.

Interest is figured at the rate of 6% per annum on the original purchase price and compounded annually Jan. 1. All the figures are brought up to Jan. 1, 1910, and the inventory value of the machines taken at this date. The yardage is a very close approximation of the actual amount mixed.

Comparison of the owned and rented plant costs for each mixer shows that there is very little saving by owning the mixers when they are over 5 years of age, as in the cases of Nos. 2 and 3. In fact, No. 2 shows a small balance in favor of renting. On the other hand, No. 6, a comparatively new machine, working on large yardage, shows a less economy than No. 3. Mixer 4, owned a little less than 4 years, rented 62.7% of the time and working on comparatively small yardage, such as reinforced concrete buildings, shows the largest economy from an owner's standpoint.

I.—First Cost and Repairs for Four Mixers

(Actually Owned)

Mixer No.	2	3	4	6	Totals
Date of purchase	8/18/03	6/10/04	6/7/06	6/5/07	
Original cost	$ 625.00	$ 975.00	$ 975.00	$ 935.00	$3,510.00
Interest at 6% to Jan. 1, 1910	281.51	368.90	220.57	153.37	1,024.35
Repairs to Jan. 1, 1910	941.87	350.29	216.43	437.01	1,945.60
Total cost to Jan. 1, 1910	1,848.38	1,694.19	1,412.00	1,525.38	6,479.95
Inventory value Jan. 1, 1910	125.00	325.00	400.00	500.00	1,350.00
Net cost to Jan. 1, 1910	1,723.38	1,369.19	1,012.00	1,025.38	5,129.95
Total yds. mixed	12,350	15,500	10,500	19,000	57,350
Plant cost per yd.	$0.1395	$0.0883	$0.0964	$0.0540	$0.0894

II.—Rental Credits for Four Mixers

Mixer No.	2	3	4	6	Totals
Days owned to Jan. 1, 1910	2,325	2,029	1,302	936	6,595
Days rented to Jan. 1, 1910	827	718	816	536	2,997
Per cent of days rented	28.1	28.3	62.7	57	45.4
Rental rate per day	$2.00	$2.25	$2.25	$2.25	......
Total rental to Jan. 1	$1,655.00	$1,616.25	$1,836.25	$1,204.50	$6,311.00
Total yds. mixed	12,350	15,500	10,500	19,000	57,350
Plant cost per yd.	$0.1340	$0.1042	$0.1748	$0.0634	$0.1100

III.—Comparison of Owned and Rented Plants

Mixer No.	2	3	4	6	Totals
Plant cost per yd., Table 1	$0.1395	$0.0833	$0.0964	$0.0540	$0.0894
Plant cost per yd., Table 2	0.1340	0.1048	0.1748	0.0634	0.1100
Per cent saving by owning plant, based on rental cost.	4.1	15.25	44.8	14.7	18.72

The cost of unloading and placing in condition for work averages about $65 to $75 per mixer.

Gravity Mixers. The most common form of gravity mixers consists of two or four small hoppers (depending upon the size

of the mixer) set upon a frame support, which latter also carries a platform on which the men are stationed to load the materials into the hoppers. Below these top hoppers three large hoppers are set, one below another. To operate the mixer after the top hoppers have been charged the gates of these are opened, and material allowed to pass into the hopper below, where it is caught and held until this hopper is full, upon which the gates are opened and the material allowed to flow into the next lower hopper and so on until the concrete is received in the bottom hopper ready to be taken to the forms. This is properly a batch mixer, but the charging is carried on while the material is being mixed in the lower hoppers.

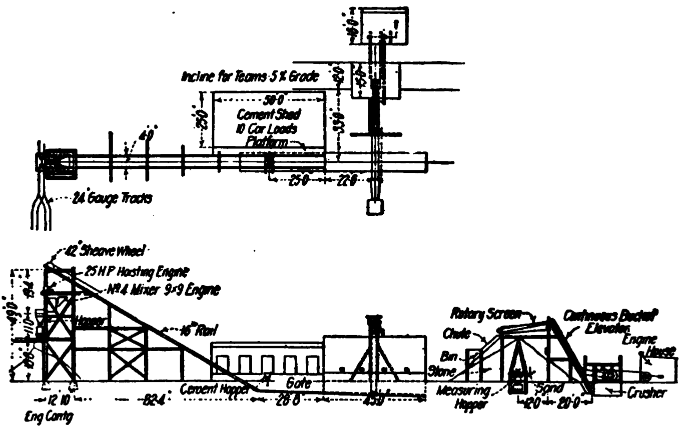


Fig. 228. Plan of Screening, Crushing and Mixing Plant, Springfield Filters.

Mr. Chas. R. Gow, in a very complete paper read before the Boston Society of Civil Engineers, 1910, gives the cost of concrete crushing, mixing and placing plant.

This plant is shown in Fig. 228. The engine used was a 40 hp. gasoline engine, but a 25 hp. was all that the plant required. The crusher was a 10 x 20 in. jaw crusher which was fed by hand with stone dumped by teams on the crusher platform. The gravel and sand were dumped on the platform and shoveled on to an inclined grating which allowed the sand to drop into a 34-ft. bucket elevator, while the larger gravel was chuted to the crusher and thence to the elevator. The rotary screen separated

the sand and stone into bins from which it dropped to a measuring hopper and thence to a skip car. This car was provided with the proper amount of cement from a hopper, was hoisted up the incline and its contents automatically dumped into a one-yard mixer which discharged into a one-yard hoisting bucket on a flat car. These cars, which had room for one empty and one full bucket, were drawn by cables along a track to the placing derricks, of which there were two, with 75-ft. guyed masts and 80-ft. booms.

This plant cost about $5,000 at the factory, $600 for freight and transportation and $3,900 to install and maintain in working condition; total cost, therefore, $9,500. It was capable of mixing 60 cu yd. per hour, but actually mixed less than 15. The total number of yards of concrete placed was 13,282, which was less than the smallest amount necessary to make the use of such a plant economical.

Cost per cubic yard for crushing, mixing and placing:

		Per Cu. Yd.
Transporting to Work:		
Freight of plant to Westfield	$0.0139	
Cost of unloading plant from cars	0.0148	
Cost of teaming plant to work	0.0161	
Total cost of landing on job		$0.0448
Final Removal of Plant:		
Cost of labor dismantling and loading	$0.0302	
Cost of teaming to railroad	0.0100	
Cost of freight returning	0.0043	
Total cost of removing plant		0.0445
Erecting and Maintaining Crusher and Concrete Plant:		
Cost of labor	$0.1725	
Cost of materials and supplies	0.1139	
Cost of miscellaneous teaming	0.0054	
Total cost of erection and maintenance of plant		0.2918
Cement Storehouse, 50 Ft. by 25 Ft.:		
Cost of materials used	$0.0205	
Cost of labor building	0.0120	
Total cost of cement house		0.0325
Erecting, Moving and Removing Derricks and Hoisters:		
Cost of labor	$0.1008	
Cost of miscellaneous supplies	0.0033	
Cost of miscellaneous teaming	0.0011	
Total cost of derricks		0.1052
Depreciation on Plant:		
Cost of depreciation on concrete plant	$0.1003	
Cost of depreciation on crusher plant	0.1370	
Total depreciation		0.1052
Coal and Oil Used in Mixing and in Operating Derricks:		
Cost of coal	$0.1222	
Cost of oil	0 0110	
Total cost		0.1332
Grand total cost of crusher and concrete plant		$0.8893

Lieutenant L. M. Adams, Corps of Engineers, U. S. A., in "Professional Memoirs" for January-March, 1911, describes a mixing and handling plant mounted on a barge for use in work in locks, dams, etc. This plant is supplied with sand and gravel from barges alongside and the concrete is removed from it by a derrick set up on the forms or on a boat adjacent. The general scheme is shown in Fig. 229. The cost was as follows:

Hull of barge	$ 4,000.00
Coal, sand (20 cu. yd.) and gravel (40 cu. yd.) bins	600.00
Boiler house and cement shed (1,000 barrels)	300.00
Derrick (55 ft. boom) complete with (8½ x 10 tandem drum) hoist, two duplicate boilers (each 30 hp.), 8 strand 19-wire plow steel rope	3,300.00
1½-yard clam shell bucket	600.00
Mixer, complete	1,300.00
Cement car (6 bags) and hoist	400.00
Total	$10,500.00
Labor cost of operation per 8-hour day shift	$16.20
Coal to furnish 40 hp. per shift	⅔ ton
Capacity, twenty 1½ cubic yard batches per 24 hours	30 yd.

In an article by Mr. Wm. G. Fargo, of Jackson, Mich., in the proceedings of the Michigan Engineering Society, 1906, several types of concrete handling plants are described. Mr. Fargo considers that on work requiring the placing of 1,000 cubic yards of concrete or over, it is usually cheapest to install a plant for handling the materials. The wheelbarrow, on large concrete works, should seldom be used. The tip car with roller bearings will enable one man to push, on a level track, from 5 to 8 times a wheelbarrow load of concrete. Wagons or cars for bringing materials to the mixer may be drawn by teams on grades of 2%, and by locomotives on grades of 4% or 5%. Steeper grades will require cable haulage. On long retaining walls or dams the cableway is especially valuable. A cableway of 800-ft. span, capable of handling a yard of concrete, will cost complete with boiler, hoist and stationary towers 45 ft. high, from $4,500 to $5,000, and for the movable towers about $1,000 more.

Such a plant should be capable of handling 20 cubic yards per hour. Where the area is wide more cableways are necessary, but if not too wide derricks may economically rehandle the load. On work where the total width is a large fraction of the length and where other conditions are favorable the trestle and car plant may be much cheaper than the cableway. When the distance from the mixers to further boundary is less than 500 ft. this is especially true. The following figures give the cost of a car plant having a capacity of 200 yards per day with length of 500 ft. out from the mixers.

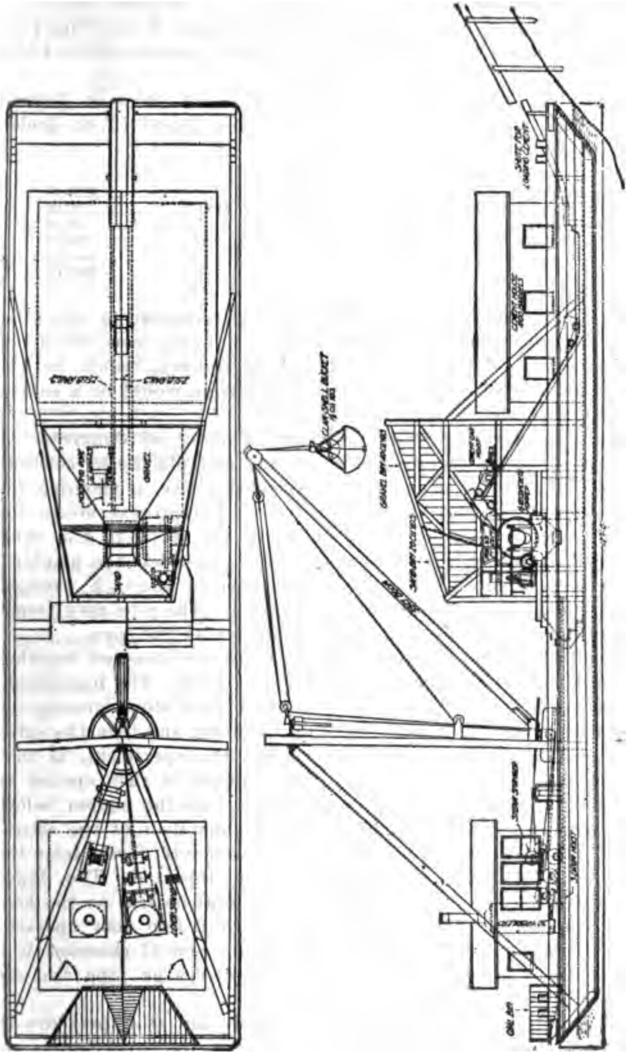


Fig. 229. General Plan of Floating Concrete Mixing and Handling Plant.

Trestle — Double track, 24-in. gauge, 6 ft. between centers of tracks; 6in. x 8-in. stringers, 22 or 24 ft. long; 2-in. x 6-in. ties, 2-ft. 6-in. centers, 2-in. x 12-in. running boards between rails, 12-lb. rail.

Trestle legs (30 ft. average length) of green poles at 5 cents per ft., will cost complete about $1.50 per lineal ft. of double track, or for the 150 ft.:

At $1.50, erected	$225.00
Five split switches, with spring bridles, at $18.00	90.00
Two iron turntables, at $30.00	60.00
Three ⅔-yd. steel tip cars, with roller bearings	190.00
	$565.00

This outfit, with repairs and renewals amounting to 10%, should be good for five seasons' work. If labor costs $1.75 per day the cost of handling 200 cu. yd. of concrete would be 4⅜ cents per yard. This, according to Mr. Fargo, would be a saving of about 5¾ cents per cu. yd.

Pneumatic Mixing, Conveying and Placing of Concrete. A patented outfit for the pneumatic mixing and placing of concrete consists of a series of hoppers suspended above a machine for the pneumatic placing of the concrete. This process mixes the concrete and delivers it to all parts of the work in the same uniform mix, either wet or dry, as when it first left the machine. The delivery pipe is either three, four, five or six inch wrought iron pipe depending on the output required. The pipe may terminate in a rubber hose of the same diameter as the pipe.

The mixer consists of two conical hoppers connected together by chains so that they hang one below the other. The ingredients are put in the top hopper as follows: the broken stone leveling the top surface, then the cement leveling the stone, and then the sand. The proper amount of water, determined by experiment, is then sprayed over the top. The door of the hopper is then opened by hand and the contents are allowed to flow into the hopper below, where they are caught and held. The hopper door of the second hopper is then opened and the mixed concrete flows into the conveyor below. The operation is then repeated. The lower section of the conveyor is of the same general outline as the hoppers. The top of the chamber is closed by a flap door operated by an air cylinder. At the bottom of the conical chamber is a 90 deg. elbow to which is attached the discharge pipe and air inlet.

The compressed air plant should supply air at a pressure of from 80 to 100 lb. The following table gives the capacities in cu. yd. per hour at the indicated distances.

Distance in ft.	Rated capacity in cu. yd. per hour. 1200 ft. free air	800 ft. free air
100	60	40
300	40	25
400	30	18
600	20	12
800	16	..
1000	12	..

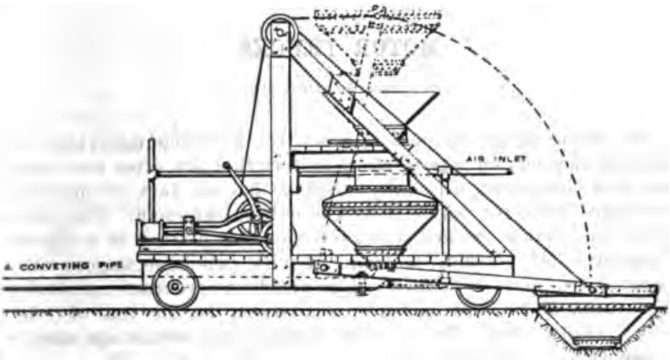


Fig. 230.

An adaptation of this machine is shown in Fig. 230. This rig is used where it is necessary to move the outfit. Special rigs are used for each particular job. This machine complete without compressor, for four or six inch discharge costs about $2,800.

SECTION 59

MOTOR TRUCKS

(See Trailers)

The value of an automobile truck for handling materials and supplies depends on a good many factors that are often not familiar to a contractor, especially when he has no data except those furnished him (for nothing) by the willing salesman. The motor truck has certain marked characteristics that place it in a distinct class by itself. When comparing it with two-horse wagons these peculiarities must be considered to avoid an erroneous conclusion. The common unit of possible comparison is the ton of "live load" transported. The cost of loading and unloading may be assumed to be the same with motors as with horses. The essential factors are, therefore, as follows:

W = net live load in tons, average,
M = dead load of vehicle in tons,
S = speed loaded in feet per minute,
KS = speed empty in feet per minute,
D = distance of haul in feet, one way,
L = lost time in one average round trip. waiting to load and unload, breakdowns, etc., in minutes,
F = fixed charges per working day, such as I = interest and insurance,
D = depreciation,
S = storage,
O = operating expenses per working day, such as f = fuel, waste, oil, etc.
L = chauffeur and other labor,
R = repairs,
m = number of minutes in the working day,
R = transportation cost per ton.
n = number of round trips per working day of m minutes.

Then we have the following formulæ:

(1) $\frac{D}{S}$ = time in minutes for a loaded trip,

$\frac{D}{KS}$ = time in minutes for an empty trip,

(2) $L + \frac{D}{KS}$ = actual non-productive time per round trip,

(3) $L + \frac{D}{KS} + D/S$ = total average time for one round trip

$$= L + \frac{D}{S}\left(1 + \frac{1}{K}\right)$$

(4) $$\frac{m}{L + \frac{D}{S}\left(1 + \frac{1}{K}\right)}$$ = total number of round trips per day. This in the majority of cases must be either an integral number or an integral plus ½, since the truck must usually tie up for the night at one end of the trip.

(5) $$\frac{m\,W}{L + \frac{D}{S}\left(1 + \frac{1}{K}\right)}$$ = Average load transported per day, in tons.

(6) $$\frac{(O + F)\left[L + \frac{D}{S}\left(1 + \frac{1}{K}\right)\right]}{m\,W} = R$$ = cost of transportation per ton for distance D

$$\frac{W}{M}$$ = weight of load divided by weight of vehicle, and

(7) $$\frac{W}{M + W}$$ = live load divided by total load, giving the measure of carrying efficiency of the vehicle.

There are eight factors composing the quantity R, and these seven formulas give us all the essential relations for determining the economic policy to be pursued for any given conditions from which the values of the eight factors can be determined.

Several of these may be taken as standard, while two, namely, the practicable net load and the distance of haul, will vary with the nature of the work and the hourly conditions on the work.

To make proper comparisons between an automobile truck and other means of transportation, the cost curves for each method should be plotted and the costs thus readily be estimated.

Motor trucks vary in price from about $1,000 for a half-ton delivery wagon to about $6,500 for a 7½-ton truck.

The prices of several makes of trucks are given as follows:

Capacity	Price f. o. b. Cleveland
¾ ton chassis, weight 2,960 lb.	$2,400
¾ ton complete, with express body	2,675
2 ton chassis, weight 4 150 lb	3,300
2 ton complete, with express body	3,600
2 ton complete, with platform body	3,550
2 ton power dump truck, with body	3,900
3½ ton chassis, weight 7,750 lb.	4.300
3½ ton complete, with platform body	4,575
3½ ton power dump truck, with body, weight 10,225 lb.	4.900
5 ton chassis, weight 7,925 lb.	5,000
5 ton complete, with platform body	5,275
5 ton power dump truck, with body, weight 10,470 lb.	5,600

Another make is as follows: (Prices for chassis.)

1¼ ton	$2090	f. o. b. Ohio
2 ton	3190	"
3½ ton	4190	"
3½ ton short wheelbase	4300	"
5 ton	5000	"
6 ton	5300	"

Truck of another make costs as follows:

1½ ton chassis	$3000	f. o. b. Ohio
2½ ton chassis	3500	"
3½ ton chassis	4400	"
4 ton chassis	4550	"
5 ton chassis	5150	"
6 ton chassis	5500	"

Another make costs as follows, f. o. b. New York:

Capacity	Shipping weight	Price
5 ton chassis	8,200	$5500
5 ton body	2,500	850
2 ton chassis	6,100	4300
2 ton body	1,500	550

The prices for the bodies include the hoist and power take-off arrangements necessary to operate them.

Prices as given are usually for the chassis alone and do not include the body, which latter may be had in a variety of forms at little above actual cost. Some types of body are very ingeniously designed and the removable body is of especial interest. This is made separate and of a size to suit the work it has to perform, and is mounted on rollers and can be removed from the chassis and rolled onto a hand truck or other support and while it is being loaded or unloaded the chassis is performing its work with another body of the same type. This is very valuable on short hauls, or where material which is difficult to handle is being carried, where the loading charge would be a large part of the total.

A make of standard straght side dump bodies built for any motor truck, trailer, semi-trailer, wagon or railroad car gear which dumps automatically by gravity and discharges the load clear of the wheels, costs f. o. b. Chicago, as follows:

Capacity cu. yd.	cu. ft.	Weight in lb.	Price Body	Center divisions	Steel covers
2	54	1000	$ 425	$30	$125
2½	67½	1200	450	30	130
3	81	1350	475	35	135
3½	94½	1550	500	35	140
4	108	1800	525	35	145
4½	121½	2000	550	40	150
5	135	2200	590	40	160
6	162	2500	675	45	....
7	189	2800	750	50	....
8	216	3100	850	60	....
10	270	3600	1000	60	....

Sectional Side Dump Bodies, the hoppers of which operate independently of one another, allowing mixed loads to be carried and dumped at separate points, are as follows: (The capacities shown are total capacities and prices are for complete outfits.)

Total cap. in cu. yd.	Price Two hopper	Price Three hopper	Price Four hopper	Weight Two hopper	Weight Three hopper	Weight Four hopper
2	$550	$ 625	....	1200	1350	....
2½	580	675	....	1450	1550	....
3	620	725	825	1650	1800	2000
3½	650	775	875	1850	2150	2400
4	680	825	935	2150	2350	2650
4½	720	875	985	2350	2600	3000
5	750	925	1025	2550	2900	3350
6	790	1000	1090	2950	3300	3700
7	850	1100	1175	3300	3700	4100
8	950	1200	1300	3600	4050	4450
10	1100	1350	1500	4100	4600	5000

Fig. 231. Standard Side Dump Body.

Fig. 232. Sectional Side Dump Body.

Three-Way Dump Body which will dump to either side by gravity and also endwise by means of a hoist, either hand or hydraulic, is as follows:

Capacity in cu. yd.	Weight in lb.	Price Round bottom	Price Flat bottom
1½	1150	$450	$ 475
2	1250	475	500
2½	1500	500	525
3	1700	525	550
3½	1850	550	585
4	2100	585	620
4½	2300	620	650
5	2450	650	725
6	2750	725	800
7	3050	800	900
8	3350	900	1000

Extra for the hand hoist: $140 for the 1½ and 2 yd. size and $160 for the rest.

Fig. 233. Standard Automatic End Dump Body.

Automatic End Dump Bodies, the dumping being controlled by a worm and gear operating mechanism, allowing the load to be dumped fast or slowly as required, cost as follows:

Capacity in cu. yd.	Weight in lb.	Price Body	Price Spreader
2	900	$425	$30
2½	950	450	30
3	1000	475	35
3½	1050	500	35
4	1200	525	35
4½	1350	550	40
5	1500	590	40

A truck body that elevates to a "tailgate height" of from 7 ft. 3 in., to 8 ft. 6 in., and then dumps, is operated by an 8 inch hydraulic hoist. The following data apply:

Capacity in tons	Shipping weight Complete	Price
2½ to 3	4500	$1700
3½ to 4	5000	1775
4½ to 5	5500	1950
5½ to 6	6000	2050
6½ to 7	6500	2225

The maximum height that the tailgate may be raised above the ground depends on the wheelbase of the truck on which it is mounted. For most trucks of 13½ ft. wheelbase this distance is 7½ ft. and with a 15 ft. wheelbase, 8½ ft. These elevations of the tailgate give the body sufficient slope to cause hard coal or any other similar material to slide to the rear and out through a chute. A slope of 50% which gives a tailgate height of about 5½ ft. is suitable for a clean dump of any adhesive material.

Hoist for Dump Bodies. A hoist that will raise a load of from 1 to 6 tons to an angle of from 35 to 50 degrees, and is operated

Fig. 234. Hydraulic Hoist Body.

by one man, furnished complete for mounting on any truck chassis costs $125 f. o. b. Kansas City, Mo. This hoist can also be used with a commercial wood body by using rear dump bed hinges with a cross rod at an additional price of $11.70. The approximate shipping weight of the hoist is 400 lb.

All Metal Dump Beds, cost as follows, f. o. b. Kansas City, Mo.:

Capacity in cu. ft.	Approximate shipping weight in lb.	List Price
up to 27	750	$310
27 to 41	850	320
42 to 54	925	355
55 to 68	1075	428
69 to 81	1175	455
82 to 95	1300	500
96 to 108	1430	550
109 to 135	1750	637

Discounts to apply to the above for straight sides 35 — 10%, flare sides 30 — 10%.

Yardage of Different Materials to Normally Load Trucks

Commodity to be handled	Capacity of Truck (Tons) 1	1½	2½	3	3½	4	5	6	7½
Ashes of Soft Coal	1¾	2½	4¼	5¼	6	7	8¾	10½	13
Brick, Common and Hard	.6	¾	1½	1¾	2	2¼	3	3½	4½
Portland Cement	¾	1.1	1.8	2¼	2.6	3	3¾	4½	5½
Cinders	1¾	2½	4¼	5¼	6	7	8¾	10½	13
Clay, dry, in Lumps ..	1.2	1¾	3	3½	4	4¾	6	7	8¾
Coal, Anthracite	1¼	2	3¼	3¾	4½	5	6½	7¾	9½
Coal, Bituminous	1½	2¼	3¾	4½	5¼	6	7½	8¼	11
Concrete Wet	½	¾	1¼	1½	1¾	2	2½	3	3¾
Earth, Moist, Packed..	¾	1.1	1.8	2¼	2.6	3	3¾	4½	5½
Gravel	.6	.9	1½	1.8	2.2	2½	3	4½	4¾
Masonry Debris	.8	1¼	2	2½	3	3¼	4	5	6¼
Sand, Dry and Shaken	¾	1.1	1.8	2¼	2.6	3	3¾	4½	5½
Crushed Rock	.6	.9	1½	1.8	2.2	2½	3	3¾	4¾
Crushed Granite	.52	.8	1.3	1.6	1.8	2	2.6	3.2	4¾

Mr. Charles L. Gow, in a paper read before the Boston Society of Civil Engineers, cites an instance where the 5½-mile road from the railroad to the work was in such bad condition and of such steep grades that 2-horse and sometimes 4-horse wagons were unable to make more than two trips per day, carrying 3,000 pounds. A steam traction engine failed of greater success on account of the bad roads and because the steep grades going up hill caused the steam dome to be flooded and going down caused the crown sheet to be uncovered. A gasoline traction engine failed because of the presence of sandy patches in the road which destroyed the tractive force of the wheels. A 2-ton 38.5 horse-power automobile truck was introduced with great success, making six trips per day over a longer but better road. However, the use of the truck on the steep, icy roads became too dangerous and was stopped during the winter. Mr. Gow says: "It is highly probable that had two of these trucks been purchased at the beginning of the work great saving would have been effected in the cost of handling materials."

Forbes & Wallace put a gasoline machine in service May 1, 1909, to deliver bundles from their department store. The result of eight months' use is as follows:

Total number of bundles delivered	2,700
Expense including storage, oil, parts and labor	$ 368.00
Tires and repairs	217.00
Gasoline	119.00
Registration	10.00
Wages	559.00
Total	$1,273.00

Depreciation, 33⅓% per annum. Cost of delivering bundles by automobile, 6½c, by horse, 9⁸⁄₁₀c.

Four Overland delivery cars were used by the United States Mail Service at Indianapolis for eighteen months. Each car replaced three horse-driven wagons and covered sixty to seventy-five miles a day.

During the winter of 1910 in New York City a motor truck carried ten cubic yards of snow, as compared with five cubic yards carried by an ordinary contractor's wagon. The return trip from the unloading point to the dock took the motor truck on an average forty minutes, while the best record trip with a two-horse truck was one hour and twenty minutes. At the rate of 36 cents per cubic yard, the motor truck earned $7.20, while the best of its horse-drawn competitiors earned $1.80. A New York contractor hauls heavy stone to the crusher and broken stone away from it. A 3-ton motor truck in one and a half days does the work that five teams took two days to accomplish.

In New York City a 5-ton truck delivered 963 tons of coal in twenty-six working days with no delay from breakdowns; it averaged twenty-eight miles per day and thirty-seven tons per day. A 10-ton truck delivered eighty-four tons a day and covered two and a half miles on each gallon of gasoline.

An industrial concern on Staten Island used one 3-ton gasoline truck, one 3-horse truck and one 2-horse truck over a round trip of twenty miles. The horse-drawn trucks made one trip each and the motor truck two trips per day. The 3-horse truck hauled 4½ tons at a cost of $10.03, the 2-horse truck hauled three tons at a cost of $7.31. The motor truck hauled six tons at a cost of $13.40

The Chicago Public Library has been using six 1-ton gasoline wagons to deliver books to their branches. They were installed in November, 1904, and the following statement was estimated to April, 1909.

Drivers' wages	$4,000.00	Machine work	$ 117.01
Gasoline	939.23	Parts replaced	1,304.02
Oil and grease	450.15	Tires	968.97
Parts	35.02	Waste	52.44
Painting	199.00	Supplies	210.78
Interest at 6%	1,080.00	Washing	600.00
Storage	800.00	Insurance	90.00
		Total	$10,846.62

Average miles per day, 33; average cost per ton mile, 18c. This service formerly cost 20c per ton mile with horse drawn wagons.

The Manz Engraving Company replaced four double teams with one 3-ton truck which made two trips daily on a round trip of more than fourteen miles. Five gallons of gasoline were used per day.

In the Boston American Economy and Reliability contest, held in October, 1910, for motor trucks, the cost of gasoline and cylinder oil per ton mile ranged from $0.0068 to $0.0892 and for the twenty-eight cars the average was $0.026, with gasoline costing 16 cents and oil costing 50 cents per gallon.

Standard speeds for motor trucks were formally adopted at a convention of the National Association of Automobile Manufacturers held in 1912. Those speeds, as reported in the *Power Wagon* of Chicago are as follows:

Load Rating	Miles per Hour	Load Rating	Miles per Hour
½ ton	16	4½ ton	9½
1 "	15	5 "	9
1½ "	14	6 "	8
2 "	13	7 "	7
2½ "	12	8 "	6
3 "	11	9 "	5½
3½ "	10½	10 "	5
4 "	10		

Types of Trucks. There are several types of motor dump trucks for use by contractors and others who handle material in bulk. These trucks are so made that the body, together with its load of from three to ten tons, can be raised at the front end and the load slid out or else raised vertically to a sufficient height to permit chutes to be used. One of these trucks has a body that is raised at the front end by a pair of chains moved by a train of gears driven from the transmission set of the truck. Another is similarly operated, except that the chains are wound up on the drums, which are worm driven from the primary shaft just back of the clutch.

There is also a dump truck that is operated by compressed air. A valve on the dash is opened to admit compressed air to a long vertical steel cylinder behind the seat. This raises a plunger whose rod is connected to the top of the front end of the body, thus hoisting the body with the load. Releasing the air from the cylinder allows the body to settle back to normal position. The compressor is operated by the vehicle engine. A new and valuable feature of some of the dump trucks are the automatic tail boards with which they are equipped. These are

hung on trunnions at the top and so connected to a system of toggle arms at the lower corners that they open automatically as the front end of the body is elevated, thus enabling the driver to dump the load without leaving his seat. Upon lowering the body the tail board closes and is locked into position.

Costs of Motor Truck Operation. The following table is from *Engineering and Contracting*, Jan. 17, 1917.

Operating Costs:

Tons capacity	Total cost	Total cost per annum	Total cost per ton mile
1	$2350	$2308	$0.246
2	3025	2544	.131
3	3650	3094	.115
3½	3900	3080	.0978
5	4300	3600	.08
5	5100	3346	.0743
5½	4550	3410	.069
6½	6100	3568	.061
7½	4800	3970	.059
7½	4900	3707	.055

The above table has been computed on the basis of:
Interest on half total investment of 6%.
Fire insurance at 2% on 80% of total investment.
Fixed depreciation exclusive of tires at 10%.
300 working days per year.
30 miles per day.
9,000 miles per year.
100,000 miles life of truck.
25 ct. per gal. cost of gasoline.
60 ct. per gal. cost of lubricating oil.
$20 per month wages.
$20 per month garage charges.

The following notes appeared in *Engineering and Contracting*, Oct. 13, 1915.

First Cost.—The first cost varies with the kind of body, the general finish, the appurtenances and other items. A very general figure for the cost of different trucks is given in Table I.

TABLE I.—FIRST COST OF MOTOR TRUCKS FOR REFUSE COLLECTION

Rated capacity, tons.	Cost of truck, complete.
1	$2,600
2	3,400
3	4,200
4	4,800
5	5,400
6	6,000
7	6,500

Operating Costs.—The cost of operating varies considerably from one locality to another. Some general data are available. Table II gives the manufacturers' estimate of the daily cost of operation, based on a travel of 40 miles per day.

TABLE II.—COST OF OPERATING GASOLINE TRUCKS PER DAY OF 40 MILES TRAVEL

Rated capacity, tons.	Cost per day.
1	$ 7.40
2	7.60
3	9.40
4	10.25
5	11.00
6	11.75
7	12.50

These figures, of course, are only approximate. They include all charges, both fixed and operating.

The *Electrical World* has compiled operating costs for electric motor trucks in commercial service from 50 plants taken from all parts of the United States. The costs include interest, depreciation, insurance, licenses, upkeep of tires, batteries, mechanical parts, power, supplies, garage charges, drivers' wages and supervision. The daily mileage is not recorded but the total cost per day is as follows for the various sizes of trucks:

Rated capacity, tons.	Average cost per day.
0.5	$ 6.34
1.0	7.56
2.0	8.92
3.5	10.38
5.0	11.74

These are quite representative figures, and are only slightly higher than the manufacturers' cost.

A study of a number of records indicates that the daily mileage of trucks will range from 25 to 40. A mileage of 30 miles per day would give the following approximate costs per ton mile, computed from the average manufacturer's figures:

TABLE III.—TOTAL COST OF OPERATING MOTOR TRUCKS PER TON-MILE

Rated capacity, tons.	Cost per ton-mile, including fixed charges.
1	$0.25
2	.13
3	.11
4	.09
5	.07
6	.06
7	.06

The Chicago Civil Service Commission, after an extended study, found the operating cost of a 3-ton gasoline truck to be $0.13 per ton mile. A 3-ton electric truck cost $0.11 per ton mile with current at 0.6 ct. per kilowatt-hour. This is a very low cost for electric power.

The Automobile Chamber of Commerce, after compiling a large number of cost data for commercial vehicles of various sizes, arrived at an average cost of operation, including fixed charges, of $0.11 per ton mile.

The Department of Public Works in Chicago uses a 5-ton and a 2-ton gasoline truck for delivering materials between city yards and construction jobs. The average cost of operating the 5-ton truck was 13 ct. per ton mile. The cost of operating the 2-ton truck varied from 14 to 32 ct. per ton mile. The cost by teams under contract was 26.9 ct. per ton mile. These costs were from actual service records during the last six months of 1914 and include fixed charges and all other costs.

These figures are from truck operation only and do not include the wages of helpers for loading in collection service.

A study of the cost of operation indicates that the fixed charges amount to about 58% of the total cost. The power cost is generally less than 10% of the total. Consequently the choice between gasoline and electric trucks does not depend wholly upon the power item, but rather upon special local conditions.

Contractors' Cost of Hauling Blasted Rock. The following data (about 1910) on motor truck work hauling blasted rock were furnished by the Charles P. Boland Company, engineers and contractors of Troy, N. Y. The contract called for the excavation and removal of 23,000 cubic yards of rock. The rock was blasted and hauled in two 3-ton trucks. These were equipped with patent dumping bodies and were used continuously, day and night shifts. The excavated material was hauled in some cases a distance of one and a half miles. The records show that these trucks carried about twice the amount usually hauled in a 1½-cubic yard dump wagon and made the trip to the dumping ground and return in just half the time required for a team to make it. Experience proved that it was necessary to keep the trucks continuously on the move in order to work them economically, and with this idea in mind large steel bottom dump buckets were used in loading the trucks; thus no time was lost in loading, as several buckets were full at all times and the operation of reloading the trucks took only the time required to hoist the buckets over the trucks. The actual loading operation required but a few minutes.

In the hauling of materials from the freight house to the build-

ing site, the records show that hauling cement cost about 1½ cents per bag, or 30 cents per net ton. Eighty bags were carried on each trip and eight trips were required to unload a car containing 640 bags. Increased efficiency was obtained by having at least six laborers to do the loading, as little time is lost if the loading force is large enough. The average record of each car of cement from the freight house to the site of operations, a distance of about 1½ miles, was as follows:

6 Laborers, 6 hrs. each day, at 16c	$5.76
1 Chauffeur, 6 hrs. each day, at 25c	1.50
Fuel, oil, etc.	.55
Percentage of maintenance charge	1.00
Total	$8.81

Referring to their experience on this work the contractors write as follows:

In the care of an automobile truck, our experience has taught us that it is economical to keep every part well lubricated at all times. A cheap or an inferior grade of oil should not be used, as the carbon forming qualities of a cheap oil more than offset the saving in the price. Where more than one truck is in use at least one chauffeur should be employed who is a thoroughly practical man. This will enable one to have each truck carefully looked over each day and any disarrangement corrected before damage is done. We have had little or no trouble with these trucks. The main expense in connection with the maintenance of the trucks is the wear and tear on tires. We are now using a wire mesh tire made by the Diamond Rubber Company which seems to give us good service. The company referred to sells these tires on a guaranteed mileage basis, and if renewals are necessary before the mileage is completed, a replacement is made by them and an adjustment made on the basis of the mileage obtained.

Operating Cost of Motor Truck in Delivering Sand and Gravel. The following is from *Engineering and Contracting*, Mar. 21, 1917.

A Pacific Coast sand and gravel company is using a 5-ton truck for delivering sand and gravel. The material is nearly always mixed and usually is quite wet. It runs 4 yd. to the load and 3,400 lb. to the yard, and is hauled over country roads of various kinds, about equally divided between gravel and dirt. There are many hills, some of them quite steep, necessitating going in first and second gears. Most of the trucking was for delivering gravel on county roads, and spreading it with the attachment on the truck. The following operating costs, furnished by the company, cover a 5-months period last year:

Average distance of delivery, miles	6.1
Cost per yard mile	$0.1055
Cost per ton mile	.0617
Total mileage	7,900
Yards delivered	5,190
Weight of gravel, 1 yd., lb.	3,400
Yard miles hauled	15,800
Ton miles hauled	28,835

Method of figuring:

$$\frac{\text{Miles per day}}{2} \times \frac{\text{yards}}{\text{tons}} = \frac{\text{yards}}{\text{tons}} \text{ per day}$$

— or —

$$\frac{\text{Miles per trip}}{2} \times \frac{\text{yards}}{\text{tons}} = \frac{\text{tons}}{\text{yards}} \text{ per trip}$$

The truck was new last year. The driver was paid for an extra hour each day the truck was operated. This extra time he put in screwing down the grease cups and inspecting parts on the truck. The driver was, therefore, held responsible for anything happening that could have been prevented by his inspection. In several instances he discovered that there was a loose nut, missing bolt, cup gone or something of minor importance, which if neglected might cause lost time and more or less expense.

These things were immediately attended to and as a consequence no time was lost on account of truck trouble.

The following data on hauling with motor trucks are from a 1920 issue of *The Commercial Car Journal:*

R. H. Gumz, paving contractor in Milwaukee, paid $1.50 per cu. yd. for hauling concrete aggregates 8½ miles from the pit to the job. The trucks hauled 5 cu. yd. to the load and usually made six trips a day. The cost of hauling aggregates this distance by team would have amounted to nearly twice that price, even if teams could have been secured at $1 an hour.

During the construction of the Beloit-Janesville road in southern Wisconsin, the contractor paid for the delivery of aggregates as follows:

$1.10 per cu. yd. on a 3⅓ to 4½-mile haul;
1.00 per cu. yd. on a 3 to 3½-mile haul; and
.90 per cu. yd. on a 2 to 3-mile haul.

The Atwood-Davis Sand & Gravel Co., from whom the aggregates were bought, delivered them on the job for the above prices, using three trucks, two trucks hauling 40 cu. yd. per day and one truck hauling 24 cu. yd. per day.

The following tables show the cost of hauling aggregates on a highway job in Luce county, Michigan, under construction during the summer of 1918. Two 5-ton trucks were used. The interest on truck investment was taken at 6% per year, and no insurance was included:

The charges for truck No. 1 were:

Depreciation, 100,000 miles (truck value minus tires)	$ 255.16
Total wages of driver	319.74
Gasoline, 1,377 gal. at 25 ct.	344.25
Lubricating oil, 117 gal. at 56 ct.	65.52
Hard oil, 128.5 lb. at 6 ct.	7.71
Waste, 20 lb. at 20 ct.	4.00
Tire depreciation, 5,316 miles at 3 ct.	159.48
Repairs and renewals	160.00
Total operating charges	$1,315.86
Fixed charges (interest)	288.00
	$1,603.86
Average haul in miles	5.54
Number of yards hauled	1,863.00
Total number yard miles performed, 10,321	$0.155 yd. mile
Total number ton miles performed, 15,481	0.104 ton mile

The charges for truck No. 2 were:

Depreciation, 100,000 miles (truck value minus tires)	$ 237.40
Total wages of driver	297 00
Gasoline, 1,235 gal. at 25 ct.	308.75
Lubricating oils, 117 gal. at 65 ct.	68.88
Hard oils, 128.5 lb. at 6 ct.	4.08
Waste, 21.5 lb. at 20 ct.	4.30
Tire depreciation at 3 ct. per mile	148.38
Repairs and renewals	131.00
Total operating charges	$1,199.79
Fixed charges (interest)	288.00
	$1,487.79
Average haul in miles	5.54
Number of yards hauled	1,780.00
Total number of yard miles performed, 9,861	$0.151 yd. mile
Total number of ton mile performed, 14,791	0.101 ton mile

The cost of hauling aggregates by motor truck for the construction of a one-course concrete road in Allen county, Indiana, was $0.011 per sq. yd. of pavement. The hauling was done with 3 and 4-ton trucks, the average length of haul being 1.7 miles. The materials were loaded mechanically at a cost of approximately 9 ct. per cubic yard, the actual cost of hauling being 42 ct. per cubic yard.

A saving of about $1,000 per mile was effected by Itasca county, Minnesota, by using motor trucks instead of teams for hauling materials on the construction of the Grand Rapids-Duluth highway in the fall of 1918. Two motor trucks of 5 cu. yd. capacity and three of 3 cu. yd. capacity were used. Figuring in all expenses for operation of trucks, and including depreciation and interest, garage charges, repairs and overhauling on completion of the work, it was found that the cost of hauling was $1·15 per yard, the average hauling being 3 miles. If the hauling had been done by teams, the cost would have been very near to $2 per

cubic yard and the cost of the road would have been increased by $1,000 per mile.

During the construction of the Belair road of the Maryland State Highway Commission, in the spring of 1919, wet concrete was delivered from a central crushing and mixing plant to the road surface by motor truck over hauls ranging from ¼ to 4 miles. Extensive rehandling of materials was thus dispensed with and the cost of the work reduced. In spite of the length of the haul, there was no apparent injury to the quality of the concrete mixture. As there was excellent stone in the hills adjacent to the road, a location was selected about midway on the contract, a quarry opened and a crushing and mixing plant installed. A 3 ft. strip of concrete 8 inches thick was built on each side of the macadam road. The mixed concrete was dumped from the trucks upon the surface of the old road and shoveled into the forms at the side. Forty cubic yd. of concrete were placed per day, the average cost of hauling being $1.76 per cu. yd.

Cost of Operating Truck and Trailer. The following appeared in *Engineering News Record*, Nov. 28, 1914.

A test was made recently at Kenosha, Wis., to determine the possible saving in the use of a four-wheel drive, brake and steer motor dump truck with trailers for hauling material 2.7 mi. from railroad cars in connection with the building of a concrete road. At the time of the test the work was being done by mules and wagons, at a cost of from $54 to $60 per day. With the motor outfit it is asserted that a saving of $35 per day was effected.

Using the mules or horses with 1½-yd. Bain patent dump wagons four trips per day were being made. The charge was $6 for team, wagon and driver. Hence the cost per cubic yard of material hauled was $1. The contractor usually employed nine or ten extra teams for this work. About 2,000 cu. yd. of material to the mile had to be hauled. For the stretch over which the test was made half the distance was good concrete road, while about ½ mi. was loose sand.

After several test trips with the motor equipment it was found that the best results were obtained by using four trailers, leaving two at the team track to be loaded while the others were being hauled; hiring enough extra shovelers at the team track to keep the specially devised 8-yd. hopper full for the arrival of empty trailers; using one of the teams on the job to reverse the trailers while the truck was being turned around at the construction end, and letting the driver do nothing else but drive. Under these conditions it was found possible, with liberal allow-

ances for delays, to make the time indicated under the table "Time Required for Round Trip."

TIME REQUIRED FOR ROUND TRIP

Item.	Time.
Time to load truck	2 min. 0 sec.
Time to pick up loaded trailers	0 min. 45 sec.
Running time to job	22 min. 15 sec.
Time to dump truck and trailers, turn trailers around, reverse truck and couple up again	9 min. 45 sec.
Running time to team track, empty	15 min. 15 sec.
Total	50 min. 0 sec.

SUMMARIZED COMBINED COSTS OF TRUCK AND TRAILERS

Fixed costs per day:	
Trucks	$5.17
Trailers	0.88
Total	$6.05
Variable costs per mile:	
Truck	10.85 cents
Trailers	2.30 cents
Total	13.15 cents

At this rate twelve round trips per 10-hr. day can be made.

The truck was a "Quad," furnished by the Thomas B. Jeffery Company, of Kenosha, Wis., which company conducted the test and gave the results in a copyrighted pamphlet from which the foregoing was abstracted. The contractor was George Wade.

The following article appeared in *Engineering and Contracting* issue of Jan. 1, 1919.

In maintaining county roads in the vicinity of Denver the Colorado Highway Department is employing a tractor, trucks, and a sand elevator, screen and loader. The complete outfit consists of the following: One C. L. Best caterpillar gas tractor of 40-hp. drawbar capacity, weight 28,000 lb., costing $6,000; one grader with scarifier and blade attachment, costing $800, and two light drags; 2 White 5-ton trucks and a Kelly-Springfield 5-ton truck, costing $6,000 each; and a Gallion sand elevator; screen and loader, costing $1,500.

The tractor, grader and one drag are generally used together and can be operated by two men. If the work is simply dragging, or smoothing with the grader, a distance of 20 miles might be covered; that is, if one round trip is made they would cover 10 miles of road; if two round trips were necessary, then 5 miles of road would be covered. The latter figure might be taken as an average in all kinds of materials for the dragging.

In many places it is necessary to scarify the surface in order to reshape it and remove the chuckholes and waves. On work of this latter class the tractor and grader are used very successfully, except on macadam or very solid gravel roads, where it is found that the scarifier is too light and it is necessary to use the heavy-toothed scarifier. On scarifying and reshaping it has been found that about ½ mile per day would be an average day's work.

The sum of $50 per day has been taken as the cost of the operation of this particular outfit. This figure is obtained as follows:

Caterpillar tractor, expense per day:		
Gas and oil	$17.00	
Maintenance	9.50	
Operator	5.00	
Depreciation (based on assumption of life of 4 years for engine and 180 working days in each year)	8.50	
		$40.00
Grader and scarifier, expense per day:		
Maintenance	$ 3.00	
Labor	4.50	
Depreciation (based on 180 working days per year)	2.50	
		$10.00
Total		$50.00

Some unsatisfactory features should be noted: The tractor is very heavy and an unsafe load on many of the old bridges. It is unwieldy, requiring a cross-road intersection or a full width road for turning. The lighter size tractor of 25-hp. at the drawbar is free from these objections, and will do most of the work that can be done with the larger size.

In charging up the work to the various roads the following has been adopted:

Expense for the year:	
Operator, 10 months, at $100	$1,000
Maintenance, oil and gas	2,000
Depreciation, 25% of the cost	1,500
Overhead and incidental	900
Total	$5,400

For 180 working days this equals $30 per day. The charge for the sand elevator and loader is based on the following:

Operator, 180 days, at $3.50	$ 630
Gas and oil, 180 days, at $1.50	270
Repairs and maintenance	450
Depreciation, 20% of cost	300
Overhead, labor, teams and incidentals	2,850
Total	$4.500

For 180 working days this equals $25 per day, and this rate is charged to the road upon which the work is being done.

The following is from *Engineering and Contracting*, Apr. 2, 1919.

The cost of hauling with motor trucks in highway work in 1918 in Luce County, Michigan, averaged about 10 ct per ton mile. Two 5-ton White trucks were employed. The interest on the truck investment was taken at 6% per year and amounted to $288 for each truck. There was no insurance. The charges for Truck No. 1 were as follows:

Depreciation 100,000 miles (truck value minus tires)	$ 255.16
Total wages of driver	319.74
Gasoline, 1,377 gal. at 25 ct.	341.25
Lubricating oil, 117 gal. at 56 ct.	65.52
Hard oil, 128.5 lb at 6 ct.	7.71
Waste, 20 lb. at 20 ct	4.00
Tire depreciation — 5,316 miles at 3 ct.	159.48
Repairs and renewals	160.00
Total operating charges	$1,315.86
Fixed charges (interest)	288.00
	$1,603.86
Average haul in miles	5.54
Number of yards hauled	1,863
Total number of yard miles performed, 10,321	$0.155 yd. mile
Total number of ton miles performed, 15,481	0.104 ton mile

Seven and One-Half Ton Trucks. The following is from the Sept. 22, 1915, issue of *Engineering and Contracting.*

The Northern Construction Co. sublet the hauling of the aggregates from their plant to the road to the C. A. Miller Cartage Co., Elkhart. This company used three 7½-ton motor trucks built by the Mack Brothers Motor Car Co., Allentown, Pa. Two of the trucks were bought in 1914 and the third is a year older.

The minimum length of haul, which is from the plant to the beginning of the road, is 2 miles, and the maximum 5 miles. Except for a short distance over city pavements, the route which the trucks have to follow is over deep sand roads which cut down their capacity of 125 miles per 10-hour day by about 20%. As an average, for their first and longest haul, the trucks made ten round trips per day, carrying a load of 4 cu. yd. of material each trip.

The working day was from 10 to 12 hours long, five days a week, and on Saturday from 5 to 10 hours. As nearly as could be determined the average came very close to 10 hours for six days; 60 hours a week, and it is on this basis that the cost of hauling is computed in the following table. As the C. A. Miller Co. uses the trucks to haul coal in the winter, they are

idle very little of the time. In figuring interest on capital invested, etc., it was assumed that the trucks were in operation 275 full days out of the year.

COST OF HAULING SAND AND GRAVEL BY MOTOR TRUCK

Length of haul, one way, 5 miles

Item	Per 10-hr. day
Labor:	
Driver at $18 per week	$ 3.00
	$ 3.00
Interest, etc.:	
Interest on cost, $5,250 at 6%	$ 1.15
Depreciation, 15% per annum	2.87
Insurance (liability and fire), $56 per annum	.20
Repairs	.38
	$ 4.60
Running expenses:	
Gas, 25 gal. at 11 ct.	$ 2.75
Oil 2½ gal. at 40 ct.	1.00
Hard grease, ½ lb. at 28 ct.	.14
Tires renewed once every two years at $400	.73
	$ 4.62
Total cost per truck	$12.22

Cubic yards hauled one mile in one day (return trip empty), $10 \times 5 \times 4 = 200$.
Cost per cu. yd. per mile, $0.0611.

Assuming that wet sand and gravel weighs 120 lb. per cu. ft. or 1.62 tons (3,240 lb.) per cu. yd.

Cost per ton mile, $0.0377.

SECTION 60

PAINT SPRAYING EQUIPMENT

Paint spraying outfits are efficient on large jobs. The manufacturers claim that one man operating a paint gun can do the work of from three to ten or more skilled painters, depending on the nature of the work. Painting by machine has also the following advantages over the hand method. Finished coats are

Fig. 235. Paint Spraying Outfit.

uniform and free from brush marks, rough surfaces difficult to coat with a brush are easily covered, and where single coat work is required, either a lighter or heavier coat can be obtained than is possible with hand brushes.

The type of paint spraying outfit generally in use consists of a source of compressed air, which may be either a portable compressor or piped from the main, a tank into which is put the paint, the control head of the tank, the paint gun, or hand device which is fitted with the nozzle and trigger valve, and suitable hose with connections.

A paint spraying outfit without the compressor is illustrated by Fig. 235. This consists of a paint gun with adjustable spreader attachments, a pressure control head, a 3–5 gal. material container, a 12 ft. length of 1/4 in. flexible, metal-lined material hose, and a 12 ft. length of 3/8 in. heavy rubber air hose with

Fig. 236. Complete Paint Spraying Outfit.

necessary renewable couplings. The shipping weight of this outfit is approximately 70 lb. and the price is $125 f. o. b. factory.

Another make of painting machines costs as follows:

Outfit No. 62, used on large painting jobs, consisting of a 3-hp. gasoline engine, air cooled compressor, 20-gal. tank, 8-gal. painting unit, air brush, 25 ft. of hose, all mounted complete on a steel truck. Shipping weight approximately 1,250 lb., price $450.

Outfit No. 60, same as above, with 3-hp. electric motor, $540. Metal housing for either outfit $35, shipping weight 85 lb.

Outfit No. 55, rated to do the work of 4 men, 2-hp. engine, 20-gal. pressure tank, air cooled compressor, 8-gal. painting unit, air brush and 25 ft. hose, all mounted on steel truck complete. Shipping weight about 675 lb., price $300. Also to be had with electric motor at the same price. Fig. 236.

Outfit No. 69B, 20-gal. painting unit complete with hose and air brush mounted on wheels, shipping weight about 160 lb., price $184.

Outfit No. 69, similar to above, weight 120 lb. for shipment, cost $135.

Nap Sack Outfit, 3-gal. capacity complete, shipping weight 18 lb., price $56.

Stack Painting Equipment used without scaffolding, consisting

Fig. 237. Stack Painting Equipment.

of an 8-gal. tank, air brush, 50 ft. of air line hose, 250 ft. rope and safety block and tackle costs $150. Fig. 237.

Other equipments are 8 and 4 gal. units mounted on a stationary base, weighing 60 and 45 lb. for shipment aand costing $78 and $68 respectively. 8-gal. unit, vertically mounted on wheels, weighs about 65 lb. and costs $85. A double tank, two color painting outfit costs complete $134 and weighs 125 lb. for shipment.

All prices for this make are f. o. b. Chicago.

A comparative test of applying paint with a spraying machine and by hand was made at the United States Naval Hospital in Sept., 1919.

In the wall test an experienced spray brush operator started the spray on one side of the building, and two experienced painters with 4½-inch brushes started on the other side of the building, which was exactly the same in size, etc., as the one selected for the machine work. After about one-fifth of the building was coated by machine, the operator of the spray brush was changed to a man unfamiliar with the use of the gun. The following is a summary of the data obtained from the test.

WALL TESTS (EXTERIOR)

Method of application	Area of surface sq. ft.	Paint used, gal.	Time, 1 man, hours	Spreading rate per gal., sq. ft.	Time to coat 100 sq. ft., min.
First coat:					
Machine	4,182	6.5	9¼	570	13.5
Brush	4,094	5.97	20	648	29
Second coat:					
Machine	4,182	4.3	10½	863	15
Brush	4,094	3.9	21	992	30.7

In addition to the above, data were obtained on the coating of a large area of the roof with the machine. Nearly 9,000 sq. ft. of surface were coated with 22½ gal. of paint in 14 hr. by one man. This included the time to mix the paint, place it in the containers, raise the machine to the roof, etc. The average journeyman painter, working on wall work will do about 200 sq. ft. an hour and about 250 sq. ft. an hour on roof work. It will be seen from the preceding test that the painters were evidently interested in the test and speeded up thir hand brush work, and accordingly have made higher averages than the figures just given. The results of the roof test follow:

Method of application	Area of surface sq. ft.	Paint used, gal.	Time, 1 man, hours	Spreading rate per gal., sq. ft.	Time to coat 100 sq. ft., min.
Machine	578	1.49	½	386	5.2
Brush	578	1.35	1½	428	15.5

The paint used in this test was a white lead paint, the materials were mixed by the men. It was tinted with ochre. The first coat weighed 17.6 lb. per gal., and the second coat 20 lb. Both paints were easily handled by the paint gun. From observations it is apparent that the spray machine will handle paint of almost any weight per gallon.

On the first coat the hand work showed a smoother appearance

than the work done with the gun. On the second coat no appreciable difference was noted. Both kinds of application took about the same time to dry.

SECTION 61

PAULINS

Canvas coverings for protecting cement, brick, machinery, etc., from the weather.

Size, feet	White No. 80 U. S. Army	White No. 100 U. S. Army
7 by 7	$ 4.33	$ 6.13
8 by 10	7.07	10.00
9 by 12	9.54	13.50
11 by 16	16.96	25.50
14 by 18	23.50	32.25
14 by 24	29.68	42.00
16 by 30	46.55	65.88
18 by 42	70.49	79.75
23 by 50	106.00	150.00

SECTION 62

PHOTOGRAPHY

No construction work, however small, should be carried on without the assistance of the camera. For motion study it is indispensable, and, as an adjunct to the keeping of records, nearly so. Photographs of construction work have saved many dollars to the contractor in employees' damages suits, and to the owner or contractor in other legal cases.

On unimportant work, pictures less than 4 x 5 inches are sufficiently large for all purposes, as small pictures can be enlarged to 8 x 10 inches or more, if necessary. After much experimenting in this line, the author uses an Eastman folding pocket kodak No. 3, which holds a 6 or 12-exposure film roll, and takes a picture 3¼ x 4¼ inches. This type of camera is convenient as it occupies very little space when folded. The picture is large enough to show fair sized groups and details.

On important work large pictures should be taken not less often than once each month, and more frequently if the work is of sufficient size and progress to warrant the expense. For this purpose the Empire State plate camera, taking a picture 8 x 10 inches, is recommended. For general use a No. 5 Goerz Dagor F: 6.8 or U. S. 2.9 lens is very good. When this lens is wide open it covers a 7 x 9 inch plate; when open at F:16 or U. S.:16 it covers an 8 x 10 inch plate, and at F:32 or U. S.:64 it covers a 12 x 16. For a wide angle lens the No. 2, listed to cover a 5 x 7, has a greater speed and better definition than a regular wide angle lens. While this lens is listed to cover a smaller plate than 8 x 10 it is actually large enough. This lens is convertible; the full combination — equivalent focus 10¾ inches — may be used for general work and the back combination — equivalent focus 21 inches — for objects at a distance.

For glossy prints, to show extreme detail, use glossy Velox; for general results, but extreme detail, velvet Velox. In order to secure compactness use the ready made developer. The "Tabloid" brand is very handy. Always keep a 10% solution of bromide of potash at hand to slow down the developer. A room 4 ft. x 6 ft. is all that is necessary for developing pictures.

If there is a window, cover it with a piece of red glass and 2 sheets of yellow P. O. paper, or with the red and yellow fabrics made for photographic purposes.

For much of the data in the foregoing article I am indebted to Mr. A. A. Russell of Flushing, L. I.

There is an excellent article in *Engineering News*, Nov. 19, 1908, page 552, on "Industrial Photography," by S. Ashton Hand.

Except where construction work is in isolated places, it is not necessary to develop films or plates on the job as practically every town whether large or small has a photo developing station.

When it is necessary to have an outfit on the job, it should include, beside the dark room, a suitable number of trays for developing, washing and fixing, graduate glasses, wide mouth bottles, printing frames, photo clips and a ruby lamp. The chemicals and full directions for their use are to be had at any supply store.

There is a wide variety of patented developing machines and other like appliances, some of which are arranged so that it is possible to develop without the use of the dark room.

SECTION 63

PICKS AND MATTOCKS

Net prices at Chicago for picks and mattocks, in quantities are as follows:

Railroad or Clay Picks weighing 7½ lb. cost $16 per doz., weighing 8½ lb. cost $18 per doz.

Drifting Picks weighing 4½ lb. cost $15 per doz., weighing 6 lb. cost $17.50 per doz.

Mattocks, adze eye, with long cutter weighing 6 lb. cost $17 per doz., weighing 5½ lb. with short cutter cost $16.50 per doz.

Pick Mattocks weighing 6 lb. cost $17 per doz.

Asphalt Mattocks. The net prices for asphalt mattocks in quantities, at Chicago, are as follows. For a mattock with crucible steel cutter and chisel ends, weighing 9 lb., the cost is $24 per doz. A mattock with double cutter, weighing 10 lb., can be bought for $33 per doz.

SECTION 64

PIER AND FOUNDATION EQUIPMENT

Piers and Foundations for the Chicago, Milwaukee & Puget Sound Ry. Bridge Crossing the Columbia River.* The bridge crosses the Columbia River about 420 miles from its mouth. At this point the river has a width at low water of 1,050 ft., at average high water of 2,800 ft., and at extreme high water of 4,500 ft. The bridge is 2,898.84 ft. long; its approaches are timber trestle on concrete pedestals and are 1,315.58 ft. and 323.58 ft. long respectively The principal dimensions of the piers are given in Table I. All piers have a batter of ½ in. to 1 ft. on the sides and downstream end of 3 in. to 1 ft. on the cut-waters. The footings vary in width from 13 to 32 ft. and in length from 32 to 60 ft.

TABLE I.—TOTAL COST OF THE PIERS, DISTRIBUTING ALL GENERAL AND INCIDENTAL EXPENSES

Pier	Width under coping	Length under coping	Height overall	Cu. yd. of concrete	Total cost	Cost per cu. yd of concrete
"A"	6′ 6″	25′ 6″	34.8′	290	$ 5,458.62	$18.82
1	8′ 0″	30′ 5⅛″	39.1′	500	9,933.79	19.84
2	8′ 0″	30′ 5⅛″	39.0′	498	9,709.65	19.40
3	8′ 0″	30′ 5⅛″	39.1′	500	9,611.64	19.22
4	8′ 0″	30′ 5⅛″	38.5′	490	11,391.38	23.25
5	8′ 0″	30′ 5⅛″	39.2′	503	10,953.16	21.77
6	8′ 0″	30′ 5⅛″	40.1′	572	11,692.62	20.44
7	8′ 6″	31′ 7⅜″	43.3′	622	16,369.79	26.32
8	9′ 0″	32′ 9⅛″	59.6′	1,404	42,792.03	30.48
9	9′ 0″	32′ 9½″	64.0′	1,506	42,283.20	28.07
10	10′ 0″	30′ 1″	91.0′	2,363	58,078.26	24.58
11	10′ 0″	30′ 1″	92.4′	2,452	63,925.50	26.07
12	8′ 6″	31′ 7⅝″	41.0′	584	13,328.93	22.82
13	8′ 0″	30′ 5⅛″	41.5′	528	11,139.24	21.09
14	8′ 0″	30′ 5⅛″	38.5′	487	9,685.11	19.89
"B"	6′ 6″	25′ 6″	29.4′	240	5,133.13	21.38
Total				13,539	$331,519.05	$24.49

For 12 land piers, 5.814 cu. yd.; an average cost per cu. yd. of concrete $21.40
For 4 river piers, 7.725 cu. yd.; average cost per cu. yd. of concrete 26.81

* Condensed from a paper by R. H. Ober, before the Pacific Northwest Society of Engineers. Proceedings Vol. IX, No. 3, December, 191

Transporting Construction Materials. About 14,000 tons of material and supplies were required for the construction of the bridge substructure and of the line near the river. The cost of freighting material across country by wagon from the nearest railroad, a distance of about 35 miles, was estimated at $12 per ton. This cost and the character of the service, with its delays and uncertainties, made this impracticable, and it was determined to handle all freight by river if possible. Navigation between the site of the bridge and a supply point on the river below the Cabinet Rapids, about one-half mile from Vulcan Station on the Great Northern R. R. and 8 miles below the Great Northern bridge, was considered to be practicable for light draft river steamers. Arrangements were made for the construction of a stern wheel river steamer of the type generally used on the upper Columbia River, and the steamer *St. Paul* was built at Trinidad and placed in commission on October 30, 1906. The principal dimensions of the steamer are as follows:

Length of hull		115 ft.
Beam		22 ft. 6 in.
Beam over guards		25 ft.
Draft light	about	18 in.
Draft loaded	about	3 ft.
Gross tonnage	about	200 tons
Actual freight capacity		112 tons
Engines, high pressure, non-condensing, with cylinders 10 inches diameter, 48 inches stroke, boiler pressure		200 lb.

This steamer cost about $11,000 to build and was used not only for handling materials and supplies but also for towing and tending at the bridge, handling barges, etc. The operating expense for a period of about 27 months was as follows:

Fuel	$10,200
Wages of crew and charter of steamer	28,800
Total	$39,000

The cost of unloading and handling freight from the cars at Vulcan to the steamboat landing, about one-half mile distant, by wagon, was about $2 per ton. The cost of handling by steamer from Vulcan to the bridge, a distance of about 36 miles, ranged from about $1 to $4 per ton, varying at different stages of the river, averaging approximately $1.80 per ton, making the cost of freight from the cars to the bridge about $3.80 per ton.

Contract. A contract was entered into, on a percentage basis, for the construction of the substructure and trestle approaches, and for the erection of the falsework for the superstructure.

Under this contract the contractor furnished all tools, outfit,

machinery and equipment necessary for the doing of the work, with the exception of equipment of a nature not generally used by the contractor and of a character peculiarly required by the nature of the work to be done, which latter equipment was furnished by the railway company. The plant furnished by the contractor included the following:

6 hoisting engines.
5 stationary engines.
1 rock crusher and engine.
2 concrete mixers.
2 eight-inch centrifugal pumps.
2 six-inch centrifugal pumps.
4 steam pumps.
3 steam boilers, 40, 60 and 80 hp.
2 steam drills.
6 derricks.
2 pile drivers.
1 steam hammer.
1 electric light engine and dynamo.
12 dump cars, 1½ cu. yd.
6 flat cars.
11,000 feet steel rails.
12 steel hoisting buckets.
5 skips.
2 orange-peel dredges.
1 clam-shell dredge.
37 coils of Manila rope.
10,000 lineal feet of ½" wire rope.
14,000 lineal feet of ⅝" wire rope.
12,700 lineal feet of ¾" wire rope.
900 lineal feet of 1" wire rope.
Small tools and fittings as required.

The total value of this plant was approximately $48,000 (1910).

SECTION 65

PILE DRIVERS

There are three types of pile drivers:

1. Free fall, in which the hammer is detached from the hoisting rope and allowed to fall freely upon the pile.

2. Friction clutch, in which the hammer remains always attached to the hoisting rope, and by means of a friction clutch on the hoisting engine the drum is thrown into gear or out of gear at will.

3. Steam hammer or pile hammer, which is described under that heading

A free fall hammer strikes about 7 blows a minute when the fall is 20 ft. and a hoisting engine is used. A friction clutch strikes about 18 blows per minute when the fall is 12 ft., and 25 blows per minute when the fall is 5 ft. A steam hammer strikes about 300 blows per minute. A railway pile driver is a heavy driver of the overhanging type, mounted on a flat car, either drawn by an engine or self propelled. Similarly, a scow pile driver is a pile driver mounted on a scow. A scow pile driver will drive more piles per day than a railway pile driver because there is no delay engendered by the sawing off and capping of each pile in order to allow the machine to pass over it.

Pile drivers range in height from 30 ft. up; the highest pile driver in the world in 1908 was one 108 ft. high.

A large pile driver traveling on a track was used by the government on the Columbia River Improvement. Its equipment consisted of boilers and engines for hoisting a 5,700 pound hammer and of boilers, pumps, etc., for operating a water jet. The machine had a reach on each side of 30 ft. and the height of leads above the cut-off of the piles was 80 ft. The largest pile which the leads would take was 26 inches in diameter and piles up to this size were driven by using the hammer in combination with the water jet. Piles 30 inches in diameter were driven by resting the hammer on their edges and driving with the jet. Piles as long as 150 ft. were driven on this work. The total weight of the machine was 60 tons and its cost about $12,000.

The Louisville & Nashville R. R. Co used a railway pile driver of their own make. Mr. G. W. Hinman gave the cost of operation per day as follows:

Foreman and 10 men	$22.00
Engineer, fireman and watchman	6.80
Conductor and 2 flagmen	7.00
Coal, oil and waste	2.50
Use of locomotive	12.00
For use of driver and tools	2.50
Total (prior to 1910)	$52.80

The above crew was used for building short trestles, say of 30 to 40 piles. When longer trestles were built a larger crew proved more economical because of fewer delays to trains. This pile driver was also used as a derrick and material of all kinds was unloaded with it.

Mr. Aaron S. Markley said that the Chicago & Eastern Illinois Railway used a Bay City pile driver. This was self-propelling and made about 8 miles per hour under its own steam. It was able to haul 5 or 6 cars on a level grade. When the pile driving was done within 1½ miles of a side track an engine was rarely used to haul it. The operator was paid $2.50 per day. The hammer weighed 2,800 lb., and the orginal cost of the entire machine was $4,500. Very few repairs were necessary; the chains and sprockets being about the only parts which needed renewing, and they had a life of from 1 to 1½ years. The machine, when working, drove from 40 to 50 piles per day.

Pile drivers mounted on sills for operation by a steam engine cost as follows:

Price complete without blocks, lines or engine:

Size of driver, pounds	Width of jaws, inches	Distance between jaws, inches	Price of hammer	Height of leads, feet	Total price iron work, including hammer	Woodwork complete, short sills	Total price, complete	Extra for extension sills
1,500	6¼	18	$ 67	30	$161	$270	$ 431	$ 49
1,800	6¼	18	80	30	174	270	444	49
2,000	7¼	19	88	35	210	390	600	71
2,500	7¼	19	110	40	240	445	685	96
3,000	8¼	20	124	50	288	840	1,128	102

Pile drivers mounted on sills are usually operated by horse power. When so operated the hammer on the small sizes is raised direct; on the large ones the end of a line is fastened

to a post or other deadman, carried through a tackle block on the main hoisting line, and tied to the whiffle trees. Winches, bolted to the ladder, can be used to raise the hammer but are very slow. Prices complete without blocks, lines or engine, are as per table following:

SIZES AND COSTS OF PILE DRIVERS ON SILLS.

(Prices without blocks, lines, or engines.)

Size of driver, pounds	Width of jaws, inches	Distance between jaws, inches	Price of hammer	Height of leads, feet	Price of iron work, including hammer	Price of woodwork	Total price, complete	Duty — Size of piles or piling hammer will drive
500	4¼	13	$26	24	$86	$162	$248	2"x 12" sheeting
600	4¼	13	31	24	91	162	253	2"x 12" sheeting
700	4¼	14	36	26	98	174	272	3"x 12" sheeting
800	4¼	14	41	26	102	174	276	3"x 12" sheeting
1,000	5¼	16	48	28	135	223	364	4"x 12" sheeting
1,200	5¼	16	58	28	145	228	373	4"x 12" sheeting
1,500	6¼	18	67	..	...	...	...	10" square or round piles
1,800	6¼	18	80	..	...	...	...	12" square or round piles
2,000	7¼	19	88	..	...	...	...	14" square or round piles
2,500	7¼	19	110	..	...	...	...	18" square or round piles
3,000	8¼	20	125	..	...	...	...	Heavy concrete piles

Adjustable trips, for regulating the length of stroke, cost:

For hammer of 2,500 lb. and over	$18.50
For hammer of 1,200 to 2,000 lb.	12.75
For hammer of 1,000 lb. and under	10.00

A small pile driver 30 ft. high with a hammer head weighing 2,200 lb. was constructed at the following cost. Bill of lumber for the driver is as follows:

	Ft. B. M.
2 Pieces 4"x 6"x 30' (leads)	120
1 Piece 6"x 6"x 4' (cross-piece)	12
2 Pieces 6"x 6"x 16' (base)	96
2 Pieces 2"x 4"x 32' (ladder)	43
2 Pieces 2"x 4"x 2' (ladder rungs)	24
1 Piece 4"x 4"x 26' (sway braces)	64
1 Piece 2"x 4"x 20' (long front sill)	13
1 Piece 2"x 4"x 14' (short rear sill)	3
1 Piece 12"x 12"x 4' (drum)	48
30 Pieces 1"x 12"x 6' (bull wheel)	180
Total	603

Two carpenters and two laborers built this driver in two days, total cost was:

700 feet B. M. at $20.00	$ 14.00
Bolts and nails	2.00
Labor	18.00
1,200 lb. pile hammer	50.00
1 pair nippers	5.00
1 snatch block	3.00
240 feet of 1-in. rope	10.00
Total, prior to 1910	$102.00

The City of Chicago in 1901 constructed some intercepting sewers by day labor. Wakefield sheet piling 2 x 12 in. x 20 ft., Norway and Georgia pine lumber, surfaced one side and one edge, was used. It was found that Norway pine would stand

Fig. 238. Special Traveling Pile Driver.

about 50% more blows under a drop hammer. The city built with its own labor a turntable drop hammer pile driver. The hammer weighed 3,000 lb. The driver was equipped with a 7 x 10 inch double-drum hoisting engine and a duplex steam pump for jetting. The leads were 40 ft. long. It cost $2,200. In operation it was found practical to swing the driving apparatus about once each day. In ordinary driving the crew averaged 90 pieces of sheeting in 8 hours, which is equivalent to 45 ft. of trench. The pile driving crew consisted of 13 men costing $40.66 per day, which gives a cost of 90 ct. per ft. of sewer. The bill of material required for 90 ft. of piling was as follows:

10.8 M., B. M., 2 x 12-inch x 20-foot timber, @ $22.00	$237.60
900 50 D spikes, @ $2.65 per 100	23 85
1 ton of coal for pile driver	2.90
Total	$264.35

This gives a cost of $5.87 per ft. of trench, or a total cost of $6.77 per ft.

During the six months ending June 30, 1910, the cost of repairs to all pile drivers on the Panama Canal work was an average of $9.42 per day for 442 days of work.

The pile drivers used on the work of improving Lincoln Park, Chicago, during 1910 and 1911, were of the drop hammer type, equipped with 45 ft. leads and 2,400-lb. hammers. The cost of operation of Driver No. 1 during 1910 was as follows:

Hours in commission	768
Labor operation	$2,629.70
Fuel and supplies	48.,90
Labor repairs	515 78
Towing, 4½ hours, @ $2.72	12.24
Insurance	85.00
Total cost	$3,728.62
Cost per hour	4.74

The cost of operation and repairs on Drivers No. 1 and No. 2 during 1911 are here given. The extensive repairs, including a new deck house and a new boiler to fit driver No. 2 for work, accounts for the high repair cost for that machine.

COST OF OPERATION AND REPAIRS OF PILE DRIVER NO. 1

Hours in commission		1,135
Operation:		Per hour
Labor	$4,962.22	$4.37
Fuel	215 65	.19
Supplies	325.80	.29
Watching	225 04	.20
Insurance	79 20	.07
	$5,807.91	$5.12
Repairs:		
Labor	$ 550.28	$0.48
Material	194.04	.17
	$ 744.32	$0.65
Total operation and repairs	$6,552.23	$5.77

COST OF OPERATION AND REPAIRS OF PILE DRIVER NO. 2

Hours in commission		634
Operation:		Per hour
Labor	$2,771 85	$4.37
Fuel	126.80	.20
Supplies	184.77	.29
Watching	132.30	.21
Insurance	79.20	.13
	$3,294.92	$5.20

Repairs:		
Labor	$1,237.89	$1.95
Material	676.57	1.06
Derrick	60.58	.10
	$1,975.04	$3.11
Total operation and repairs	$5,269.96	$8.31

Steam or Air Hammer. The principle of operation is the alternate rapid rising and driving down of a ram of considerable

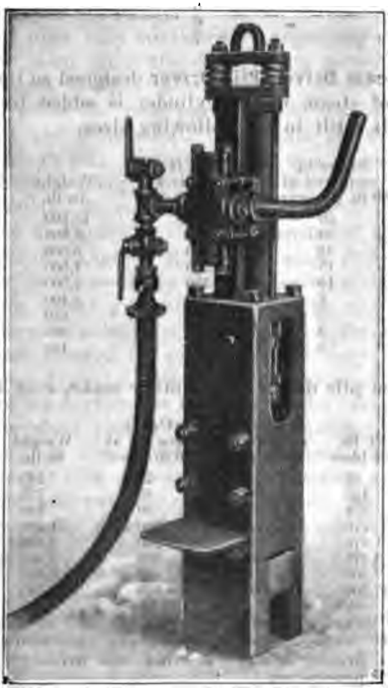


Fig. 239. Steam or Air Pile Driver for 3-in. Sheeting.

weight, by steam or compressed air. It gives a lighter blow than the drop pile hammer, but its blows follow each other so rapidly that the pile and the ground do not have time to settle back into their normal static condition before the next blow

strikes the pile. It does not split or broom the pile head as much as the drop hammer does, and it holds the pile more steady.

The hammer illustrated in Fig. 192 can be suspended in the leads of a pile driver or hung from a derrick, crane or beam. Table 127 gives the sizes, weights, prices, etc., including fittings for attaching hose to hammer but no hose. Hose costs as follows:

Size, inches	Number of plies	Price per foot
¾	5	$1.10
1	5	1.40
1¼	6	1.60
1½	6	1.95
1¾	6	2.50
2	7	3.00

A Patent Steam Driven Pile Driver designed so that in operation the pressure of steam in the cylinder is added to the weight of the hammer, is built in the following sizes.

Total downward force in lb.*	Boiler hp. required at 80 lb. pressure	Cu. ft. free air at 80 lb. pressure	Weight in lb.	Price f. o. b. factory
7,800	50	750	12,100	$2,750
5,800	30	600	8,000	1,750
3,300	18	300	5,500	1,250
2,470	15	200	4,500	1,100
1,683	10	150	2,500	850
1,085	8	100	1,400	500
636	5	60	850	400
364	3	40	365	275
347	3	40	165	225

Steam driven pile drivers, of another make, cost as follows:

Strokes per min.	Ft. lb. per blow	Boiler hp. required at 80 lb. pres.	Cu. ft. free air at 80 lb. pres.	Weight in lb.	Price f. o. b. factory
500	81	10	75	145	$ 250
450	125	10	85	325	350
300	271	15	90	640	400
300	776	20	200	1,500	650
275	1,875	25	260	2,900	850
225	3,271	35	350	5,000	1,150
140	7,800	40	400	6,800	1,600
120	17,500	60	600	13,185	3,000

* Referring to downward force in table, the duty of hammers is usually given in "wood" units; the sheet steel piling equivalents are as follows:

Hammers driving 2″x 12″ sheeting will drive 9″ sheet steel piling to 20′ penetration.

Hammers driving 3″x 12″ sheeting will drive 12″ sheet steel piling to 20′ penetration.

Hammers driving 4″x 12″ sheeting will drive 12″ sheet steel piling to 25′ penetration.

Hammers driving 14″ round piles will drive 12″ sheet steel piling to 40′ penetration.

Hammers driving 18″ round piles will drive 15″ sheet steel piling to 60′ penetration.

SECTION 66

PILING

The prices of piles vary considerably depending on the distance of the delivery point from the distribution point. Most dealers include the freight charges in the prices quoted. The following prices were in effect the first part of 1920 for yellow pine piles of 12 inch butt and 6 inch top. Prices are per ft., f. o. b. New York, N. Y. Short leaf, 30 to 40 ft., 16 ct.; 40 to 50 ft., 19 ct.; 50 to 60 ft., 22 ct. Long leaf, 30 to 40 ft., 28 ct.; 40 to 50 ft., 30 ct.; 50 to 60 ft., 32 ct.

Cost of piling and piles in the construction of an ore dock for the Duluth & Iron Range R. R., is abstracted from an article by Leland Clapper, in *Engineering and Contracting,* July 17, 1912.

The following tables give the time of the various classes of labor and of the outfits used in carrying out different parts of the work. The time allowed for outfit includes only the time while actually in use. A 40 hp. gasoline boat did most of the towing and the time of its engineer is included in the tables.

In Table I for sheet piling, the item "preparing and handling" includes spiking on the tongues and grooves, using about 50 ⅜ x 8-in. spikes per pile, also sharpening, loading by derrick from skidway to scow, and unloading at the drives. The item "waling and tying" covers the placing of the temporary inside guide tim-

I.—Time Cost of Sheet Piling (2,350 Piles)

	Hours	Hours per 100 sheet piles
Preparing and handling:		
Foreman	370	15.58
Carpenters	520	21.89
Skilled labor	1,630	70.73
Common labor	4,950	208.40
Engineer	340	14.31
Tug and crew	40	1.68
Derrick scow	250	10.53
Driving:		
Foreman	590	24.84
Skilled labor	1,890	79.57
Common labor	2,160	90.94
Engineer	830	34.94
Drivers	570	24.00

Cutting off:		
Common labor	1,700	71.57
Waling and tying:		
Foreman	760	32.00
Carpenters	2,380	100.20
Skilled labor	6,330	266.49
Common labor	13,370	562.88
Engineer	1,960	82.52
Tug and crew	40	1.68
Derrick scow	1,040	43.78
Drivers	570	24.00

bers, the temporary outside waling timbers and all temporary and permanent bolts and anchors.

Table II for round piles includes only those piles in the dock proper. The item "pointing and handling" includes sorting, pointing, rafting and delivering to drivers. The cutting includes the removal of the old pile head.

II.—Time Cost of Round Pile Work (163,500 Piles).

	Hours	Hours per 100 lin. ft.
Pointing and handling:		
Foreman	20	.0122
Engineer	350	.2135
Skilled labor	2,330	1.4213
Common labor	2,390	1.4579
Derrick scow	130	.0793
Team	350	.2135
Driving:		
Foreman	670	.4087
Engineer	670	.4087
Skilled labor	2,670	1.6287
Common labor	2,690	1.6409
Pile driver	660	.4026
Cutting off piles:		
Foreman	130	.0793
Skilled labor	600	.3660
Common labor	3,180	1.9398

Cost of Driving Piles with a Gasoline Hoist. The following is from the July 18, 1914, issue of *Engineering News-Record*.

A reversible gasoline hoist with a 6½-hp. engine and operating a 1650-lb. drophammer has been used for driving 1,300 piles to support a stage for 7,000 singers during the St. Louis pageant. These piles were driven from a scow about 6 ft. deep in the bottom of the Mississippi River at Forest Park. The niggerhead of the hoist was used to pull the piles in place and the drum was utilized for hoisting the ram. In addition, a pulley on the flywheel ran a centrifugal pump for keeping the scow dry.

In the chart, Fig. 240, are shown the total number of piles to be driven on schedule and the actual number of piles driven,

the estimated cost of driving 1,300 piles and the actual cost of labor on piles driven. The largest number of piles driven in one day was seventy-five. In the estimate were included 17,105 lin. ft. of piling at a cost of 17 cents, giving a total cost of $2,907.85. The average length per pile was estimated to be 13.15 ft.

Actually 1,326 piles, aggregating 19,104 lin. ft. and averaging 14.4 ft., were driven. Of this number 25 piles were driven out of line, so that the useful number was 1,301 piles, aggregating 18,735 lin. ft. Allowing 100% depreciation on engine and scow, the cost of driving 18,735 lin. ft. was $2,148.38, or 11.5 cents per foot. This depreciation, of course, is excessive, and if 20% is allowed on

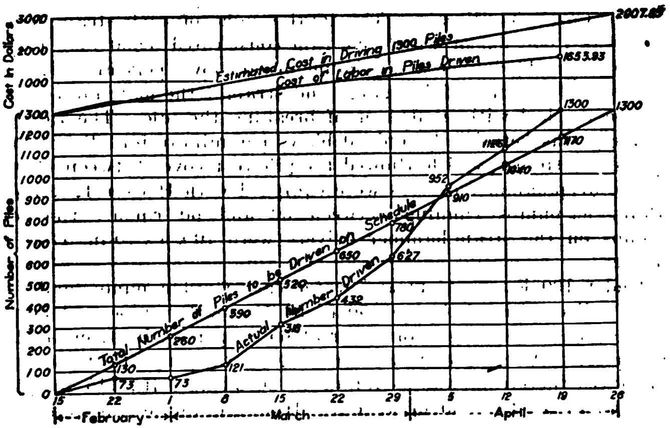


Fig. 240. Diagram of Speed and Cost of Driving Piles with Gasoline Hoist.

engine and scow and 15% for overhead charges the total cost of driving was $2,000.92 or 10.7 cents per linear foot. The cost of the piles delivered was $1,432.80 or 7.5 cents per linear foot, so that with a cost of driving of 10.7 cents the cost per linear foot of pile in place was 18.2 cents. The crew consisted of four men.

The itemized costs were as follows: Cost of piles delivered, $1,432.80; total payroll, $1,653.93; engine and hoisting outfit, $340; scow, $154.45.

Pile Penetration With and Without a Water Jet. The following is from an article by Mr. F. Y. Parker, in *Engineering News-Record*, Mar. 25, 1915.

Extensive observations of the behavior of wood piles driven

in dike construction along the Mississippi River between the Ohio and Missouri Rivers were made during the spring and summer of 1914.

The dikes consisted of three rows of three-pile clumps, 9 ft. apart, the clump piles being driven at the apexes of approximately equilateral triangles the sides of which were between 3½ and 4 ft. long.

The soil was for the most part sand and quicksand, although a certain amount of mud and some gravel were encountered.

Single-acting steam hammers and ordinary drop-hammers raised by hoisting-engines with friction clutches were used on the work. The drop-hammers weighed 2,400 lb. each; they were used with 400-lb. Casgrain pilecaps. The total weight of each steam hammer was 7,000 lb., of which the ram constituted 5,000 lb. These hammers could deliver a maximum of 60 blows per minute; but unless the piles were fairly large and straight the maximum could not be reached without danger of breaking the pile. The rate of delivery was between 45 and 50 blows per minute for all crooked and small timber, which allowed the pile to recover between blows.

The drop-hammer drivers were equipped with Hooker 12 x 6¼ x 16-in. jet-pumps running between 50 and 60 r.p.m.; the jet-pumps on the steam-hammer drivers were 10 x 6 x 10-in. Gordon duplex.

Under 100 lb. of steam and water each Gordon pump made 84 r.p.m., discharging (through 50 ft. of 2½-in. iron pipe and 50 ft. of rubber hose) 420 gal. of water at 65 lb. per sq. in. from a 1¼-in. nozzle. With the nozzle submerged, the impact at various distances therefrom was as follows: 120 lb. at 1 ft., 115 lb. at 2 ft., 100 lb. at 3 ft., 50 lb. at 4 ft. However, for jetting purposes both the Hooker and the Gordon pumps approximated 60 lb. nozzle pressure (under water) 100 ft. from the pumps.

Each jet-pump was connected to a stationary 2½-in. gas pipe, extending from the pump to the second platform, in the piledriver leads. A hose connected this pipe to coupled sections of 2½-in. gas pipe with the end section reduced to a 1¼-in. nozzle.

Before placing the jet-pipe the pile was driven several feet into the ground; driving was then stopped and the pipe placed against the pile and carefully lowered to the river bottom. The pump was then started and the pipe churned below the foot of the pile. A rope leading from the pipe through a snatchblock to the spool of the hoisting engine was used for this work. As soon as the jet became effective, driving was resumed, and the jet kept a few feet in advance of the pile until the desired penetration was secured.

When no further penetration was attained the jet-pipe was with-

drawn and relocated against the pile. Occasionally several relocations failed to give results. Often a pipe "froze" in the ground and difficulty was experienced in withdrawing it; this was overcome by keeping the pipe-to-spool line taut, and tapping the pipe with a hammer or sledge.

Difficulty was always encountered in forcing the jet-pipe through the brush foundation-mattress of the dikes, which had been made and sunk in place before piledriving started.

After starting the jet the pile would sometimes drop several feet under its own weight plus that of the hammer, and this drop was followed by a marked increase in penetration per blow. This usually immediately followed each relocation of the jet.

Neither shoes nor rings were used on the piles, but various experimental pointings were given to butts and tips.

The controlling factor in "butts or tips down" was to have, after driving, the greatest pile cross-section at the point of maximum bending moment. The desired penetration (about 20 ft.) was a constant; but the depth of water and the coning of the piles were unknown. Soundings gave the depth at pile clump locations; pile conings were estimated. From these data was estimated the greatest cross-section. In very deep or very shallow water it was only necessary to estimate the pile conings.

A number of tables were compiled giving pile lengths, penetrations and drop of hammer for each blow, diameters of piles and dimensions of sharpened points. From these records certain facts were deduced:

1. Compacting of the soil occurred at pile clumps when the water jet was not in use. The accompanying view shows the effect. The piles of this green-cypress clump were driven by a steam hammer without jetting, to the same penetration. The imprint of the ram on the pile head shows which pile was driven first and which last.

2. Both hard and soft woods were used for pile timber. When driven in connection with the jet no appreciable difference was noticed in their resistance to brooming and splitting. The kind of timber, whether green or dry, crooked, bowed or straight, bark on or off, butt or tip down, tip sharpened or square, seemed to influence "driving time" very little provided the jet was kept in proper position. Some crooked piles took longer to drive due to inability to follow pile movements with the jet.

3. Apparently the most important requisites for rapid driving were to keep the jet on line with, and a few feet in advance of, the sinking pile and to maintain the pile plumb in the piledriver leads.

4. The records indicate that chisel pointings, especially for tips,

are preferable to square ends or pencil points. When the jet was not in use, the tendency of the piles to cant was less with the unpointed square-ended piles.

5. That great differences exist in the penetrability of sands was evident; the most pronounced irregularities appear in quicksands. A mixture of sand and gravel was easier to penetrate than either sand or gravel alone.

6. The superiority of steam over drop-hammers is unquestioned.

7. Instances occurred where the performance of the jet was disappointing; but the water jet is an invaluable adjunct of the hammer and a necessary part of every uptodate piledriver equipment.

For driving average timber in ordinary soils, the writer advocates a medium-weight double-acting steam hammer striking 180 or more blows per minute in conjunction with a single-pipe water jet. The jet-pump should furnish, at a distance of 100 ft., 175 lb. pressure at a 1¼-in. nozzle submerged 10 ft. With this nozzle pressure the hammer would be merely an adjunct of the jet, and its use limited to a few blows at the beginning and end of each operation. Moreover the time required to sink a pile would be reduced to a minimum.

The standard dovetailed sheet-piling of the Southern Pacific Railway used by Mr. Kruttschnitt in closing breaks on the Mississippi levees, is described as follows in the *Reclamation Record*.

"The main body of each pile is composed of a 4 x 12-in. plank with the lower end adzed to a slope of about 15 degrees with the horizontal, so as to force the piling in driving against the preceding one. On one edge of the body are nailed two strips made of 1-in. boards, having their exterior edges in the plane of the face of the pile, and their interior edges beveled so as to form a trapezoidal groove between them with a larger base adjacent to the body of the pile. This larger base is made about 2 inches in length, the shorter base about 1 inch in length. On the other edge of the main body of the pile is nailed a single strip made of 1-in. boards and so beveled as to permit it to slip snugly between the beveled opening on the adjacent pile. The strips are nailed to the main pile with 10d wire nails spaced 6 in."

The cost of making 1 sq. ft. of this piling would be about as follows:

1 4"x 12"x 12" plank at $30 per M., B. M.	$0.12
3 2"x 1"x 12" planks at $30 per M., B. M.	.015
6 10d wire nails at $2.20 per keg	.002
¼ hour of carpenter at 50 cents per hour	.125
Total (1914)	$0.262

Pile Band Puller. Fig. 240A is a sketch, kindly contributed by Mr Arthur M Shaw, Consulting Engineer, of a pile band puller that has been found very useful in removing the iron bands from the tops of piles. It is made out of rather heavy material but should be available to any organization that has a blacksmith outfit.

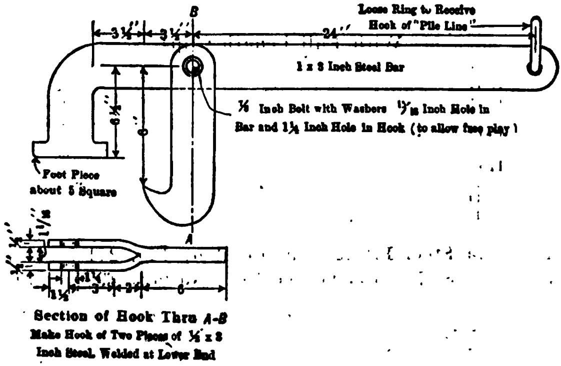


Fig. 240A.

Pulling Sheet Piling with Steam Hammer. The following notes are from *Engineering News-Record*, Dec. 18, 1915.

An inverted steam hammer pulled, in 90 sec. each, pieces of 35-ft. steel sheet piling which were used in coffer-dams for constructing the foundations of the Pittsburgh & Lake Erie Railroad's new warehouse in Pittsburgh. Mass concrete for the footings, 5 ft. thick, was poured directly against the sheeting with no attempt to prevent a bond, and the cofferdams were backfilled to the top before any pulling was done. Nevertheless, a majority of the piles were started and drawn in one minute less than the average driving time on each pile.

The rigging consisted of a wire-rope sling suspended from the crane hook supporting the inverted hammer. Over the anvil block of the latter passed a heavy strap of steel, shackled at the lower end to pulling straps pinned to the pile. The hammer, a No. 6 McKiernan-Terry, is rated at 275 blows a minute with an 8¾-in. stroke. It was supplied with steam from the crane.

Out of several car loads drawn with the hammer at Pittsburgh practically every pile was in condition for immediate redriving.

Wemlinger Sheet Steel Piling costs, f. o. b. New York, as follows:

With Short Clips

Type	Thickness	Price per sq. ft.
3-A	1/8	$0.35
4-B	7/64	.35
5-B	1/8	.39
6-B	5/32	.41
7-B	3/16	.44
8-C	3/16	.49
9-C	1/4	.52
10-C	5/16	.62

With Full Length Clips

Type	Thickness	Price per sq. ft.
11-B	7/64	$0.44
12-B	1/8	.45
13-B	5/32	.49
14-B	3/16	.52
15-C	3/16	.57
16-C	1/4	.63
17-C	5/16	.72
18-D	3/16	.74
19-D	1/4	.82
20-D	5/16	.98

Lackawanna Steel Piling illustrated by Fig. 241 costs f. o. b. Pittsburg from $2.70 to $3.00 per 100 lb. (Jan., 1920, quotation).

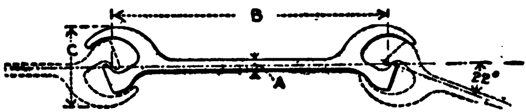


Fig. 241. 12¾-in. Piling, ⅜-in. and ½-in. Web.

Special pieces such as tees, crosses, corners, etc., take an additional 90 cents per 100 lb. It comes in any length up to 70 ft. and its other dimensions are as follows:

Thickness of Web, In. A	Weight per Square Foot of Wall, Lb.	Dist. Center to Center of Joints, In. B	Weight per Lineal Foot, Lb.	Width of Joint Over All, In. C
½	40.00	12¾	42.500	3 45/64
⅜	35.00	12¾	37.187	3 45/64
¼	21.50	7	12.54	1 53/64

This piling drives easily. In a test a 50-ft. length was driven 47 ft., under a 5-ton hammer striking 90 blows, with a penetration of 1 inch at the last blow.

Test of Driving Steel Sheet Piling, Cleveland, O. One place on the short line of the L. S. & M. S. R. R. around Cleveland, Ohio, required tunneling under the grounds of a manufacturing plant. The tunnel was to have two standard grade tracks at an elevation of about 50 ft. below yard level of this plant. The wash test borings taken at this point showed:

Below grade	
Yard level to 5 ft.	Slag and cinders.
5 ft. below to 20 ft.	Yellow clay and gravel.
20 ft. below to 30 ft.	Fine gravel.
30 ft. below to 40 ft.	Coarse gravel.
40 ft. below to 50 ft.	Fine sand.
50 ft. below to 55 ft.	Coarse sand and gravel.
55 ft. down	Hard pan (blue clay).

The fine sand, 40 to 50 ft., was in the nature of quicksand, and there was a surcharged load at the sides.

The engineers of the Lake Shore R. R. decided on steel sheet piling. This work required 60 ft. penetration. Five bars of 12¾-in ½-in. Lackawanna steel sheet piling, weighing 40 lb. per sq. ft. and 50 ft. long were ordered for this test. These bars were driven by a No. 1 Vulcan hammer, weighing 10,150 lb., total striking part 5,000 lb. with a 42-in. stroke. In general the record was as follows:

No. 1 Pile (experimenting, etc. Accurate record not taken.)

	Blows
No. 2 Pile 20 min. actual driving time	1,136
No. 3 Pile 23⅛ min. actual driving time	1,572
No. 4 Pile 35 min. actual driving time	2,284
No. 5 Pile 20¼ min. actual driving time	1,283

No. 5 pile was followed down to 10 ft. below the surface of the ground in 18⅝ minutes, with 1,153 blows. All five bars were driven to the surface of the ground, making a penetration of 50 ft.

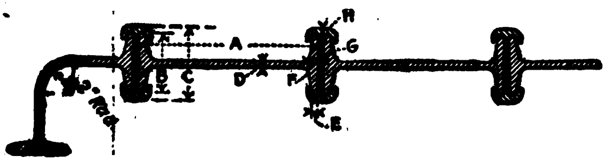


Fig. 242.

Jones & Laughlin Piling, illustrated in Fig. 242, costs about 3 ct. per lb., f. o. b. Pittsburgh. It is made in any length.

No.	Size (Ins.)	Wt. per Sq. Ft. (Lb.)
1	12 x 5	35.00
2	12 x 5	36.25
3	15 x 6	37.20
4	15 x 6	39.75
5	15 x 6	42.25

United States Steel Sheet Piling is rolled in three sizes: M 105, M 104 and M 103. It was quoted in Jan., 1920, at about $3.60 per 100 lb. f. o. b. Pittsburgh.

Section	Width in in.	Straight section weight in lb. per sq. ft.	Regular corner weight in lb. per lin. ft.
M 105	12½	39	43
M 104	12½	35	38
M 103	9	21	16

91 pieces of the 12½-in. piling should drive 100 ft. of wall. 130 pieces of the 9-in. piling should drive 100 ft. of wall.

Friestedt Interlocking Channel Bar Piling, fabricated from channels and zee bars, does not possess high interlocking strength but is adapted to ordinary construction work.

No.	Width in in.	Pounds per foot Channels	Pounds per foot Zees	Regular Corner
1	12	20.5	8.6	46
2	12	25	8.6	51
3	15	33	9.2	61
4	15	40	9.2	68

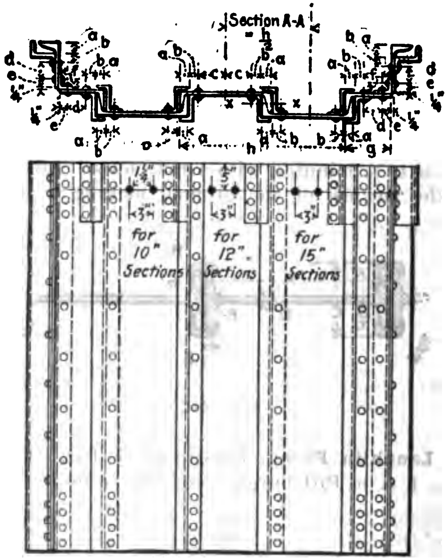


Fig. 243. Symmetrical Interlock Channel Bar Piling.

Symmetrical Interlock Channel Bar Piling similar to the Friestedt piling, suitable for difficult driving where great interlock strength is not required, is as follows: (See Fig. 243.)

No.	Width in in.	Pounds per foot Channels	Zees	Regular Corner
1	10	15	4.8	26
2	10	20	4.8	31
3	12	20.5	8.6	38
4	12	25	8.6	42
5	15	33	9.2	51
6	15	40	9.2	58

Driving. United States piling should be driven with the ball side ahead so that the loose material will not interfere with the driving. Symmetrical piling should be driven with the long Z bar ahead, which serves to stiffen the free edge of the pile. Friestedt piling may be driven alike in either direction, plain pile following Z pile alternately.

Sheet steel piling is driven in the same manner as wooden piling. In shallow trench work wooden mauls hung from a tripod may be used. In heavier work a power driven hammer is to be preferred.

The Bush Terminal Co. of Brooklyn, N. Y., decided in 1910 to substitute steel for wood sheet piling in the construction of the foundation pits of their new buildings. Each of the 288 reinforced concrete columns in these buildings requires the digging of a foundation pit 10 ft. x 12 ft. x 12 ft. deep. In excavating some of the first of these pits, the sheeting was of 2 x 10-in. wood piling which cost $1.00 per horizontal foot, including rangers, bracing and removal, making a cost per pit of about $44. This wood was good for only 2 or 3 drivings, an average of 2½.

Two hundred and fifty tons of steel piling similar to the above, of the 6-in. x 12-ft. section, weighing 11 lb. per ft., were purchased. This quantity was sufficient for about 40 pits, and it has already been re-used over 14 times, and is yet in very good condition. The bracing consists of 2 sets of 6 x 8-in. rangers with one cross-bar of the same dimensions, but it has been found that lighter bracing can be used. This piling was driven by hand, with wooden mauls for about one-half the distance, and with iron sledges for the remainder, a special cap being employed.

The average cost of 40 pits sheathed with steel piling has been $14.63 for driving and $4.84 for pulling, or about 2¾ ct. and 1 ct. per sq. ft., respectively. The steel piling cost $222 per pit, or 43 ct. per sq. ft. For the 14 times it has been re-used, this makes a total cost as follows:

Steel material	$222.00
Driving 14 times	205.00
Pulling 14 times	68.00
Total for 14 pits	$495.00
Average cost of 1 pit	35.30

Cost of Driving Steel Sheet Piling (1909)

Note.—First 34 items U. S. Steel sheet piling. Next 7 items Friestedt interlocking channel bar piling. Next 3 items symmetrical interlock channel bar piling.

	Kinds.					No. driven per day.					
	Width, in.	Weight, lb.	Net tons	Length, ft.	Penetration, ft.	Min.	Max.	Type of hammer.	Cost, cents per ft.	Material.	Remarks.
Mt. Carmel, Ill.	12	35	366	28	22	32	20	Drop	2.75	Sand, fine gravel.	....
Port Elizabeth, S. A.	12	35	96	20	15	9	4	Drop	10.60	Stiff clay silt.	Slow hammer, handling included.
Glen, Ohio	12	35	67	16	10	35	15	Drop	6.00	Riprap, sand and gravel.	
Hartnett, Pa.	12	35	38	22	22	16	11	Drop	3.00	Filled earth, clay, sand.	....
Des Moines, Ia.	12	35	85	26	16	40	35	Drop	5.00	Clay, gravel	....
Winnipeg, Man.	12	35	154	35	30	30	13	Drop	4.50	Clay hardpan.	....
St. Cloud, Minn.	12	35	61	18	18	35	20	Drop	12.00	....	Labor, fuel, oil, etc.
Decatur River, Ill.	12	35	72	14	11	..	..	Drop	11.90	Sand, gravel.	Labor and equipment.
Louisville, Ky.	12	35	113	30	21	100	80	Drop	5.00	Silt, sand.	....
Williamsport, Ind.	12	35	28	12	12	..	..	Drop	6.64	Sand, coarse gravel.	Labor and equipment.
Butler, Pa.	12	35	312	20	20	30	3	Steam	12.50	Sand, blue clay.	Price paid contractor.
Bloomer, Wis.	12	35	18	10	10	..	..	Maul	29.00	Quicksand.	Labor and equipment.
Albion, Neb.	12	35	35	26	10	14	6	Drop	10.00	Clean sand.	....
Rothschilds, Wis.	12	35	505	30	28	40	35	Steam	3.50	Coarse sand, gravel.	....
Newark, N. J.	12	35	140	25	23	20	..	Steam	11.50	Gravel, sand, hardpan.	....
Neligh, Neb.	12	35	35	20	12	26	2	Drop	8.00	Sand.	....
Hatfield, Wis.	12	35	150	35	31	15	..	Drop	21.00	Sand, clay, gravel.	Much time lost, labor and equipment.
Otisco Lake, N. Y.	12	35	46	20	18	15	3	Drop	17.00	....	
Minneapolis, Minn.	12	35	15	14	14	16	13	Steam	7.00	Sand, gravel, boulders.	....
Milwaukee, Wis.	12	35	21	30	30	30	12	Drop	7.90	Clay, quicksand, gravel.	....
Minnehaha, Minn.	12	35	182	35	29	34	13	Steam	7.40	Sand, gravel.	Labor and equipment.

This shows a saving over wood of about $9 per pit, or 20%, and the steel material is still available for future use.

The above matter has been compiled from an article by Mr. F. T. Lewellyn in *Engineering Record*.

The table on following page has been abstracted from the Carnegie Steel Co.'s booklet, "Steel Sheet Piling."

Concrete piles may be divided into two classes, those molded and hardened before driving and those molded in place. There are several patented methods of driving and molding piles in place, some presenting advantages over others under different conditions to be met in the work and soil. The Simplex pile employs a cylinder to which is fitted a cast iron or steel point; when the pile has been driven to the required depth the cylinder is filled with concrete and is then pulled out, leaving the point at the bottom and the wet concrete, settling, completely fills the hole. The Pedestal pile is constructed by driving a cylinder and core together. When the required depth is reached the core is withdrawn, some concrete is poured in and the core is then used

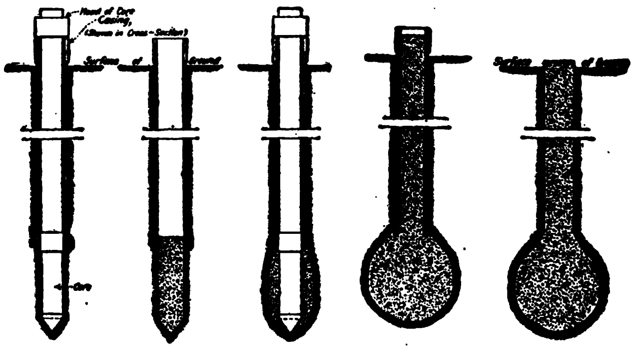


Fig. 244. Fig. 245. Fig. 246. Fig. 247. Fig. 248.

Fig. 244. A core and cylindrical casing are first driven to the required depth.
Fig. 245. The core is now removed and a charge of concrete dumped to the bottom of the casing.
Fig. 246. The core is now used as a rammer, to compress this concrete into the surrounding soil. The process is repeated until the base is about 3 feet in diameter.
Fig. 247. The enlarged base being completed the casing is filled to the top with wet concrete.
Fig. 248. The final step is to withdraw the cylindrical casing from the ground. The completed Pedestal Pile, consisting of a monolithic concrete column 17 inches in diameter surmounting a broad base 3 feet in diameter, is thus left in the ground.

Kinds.	Width, in.	Weight, lb.	Net tons	Length, ft.	Penetration, ft.	No. driven per day. Max.	No. driven per day. Min.	Type of hammer.	Cost, cents per ft.	Material.	Remarks.
Evansville, Ind.	12	35	105	20	19	86	10	Drop	0.63	Clay loam sand.	
St. Louis, Mo.	12	35	15	10	10	..	..	Drop	4.00	Clay, quicksand.	
Barrow in Furness, Eng.	12	35	92	25	24	6	4	Drop	63.00	Marl.	Driven under water — divers.
Pittsburgh, Pa.	12	35	134	24	5	105	20	Drop	5.06	River mud, silt.	
Monterey, Mex.	12	40	130	24	20	28	5	Drop	9.00		
Evansville, Ind.	12	46	81	20	20	31	26	Drop	5.00	Close packed sand.	
Evansville, Ind.	12	40	81	20	17	31	26	Drop	10.00	Close packed sand.	
Kilbourne, Wis.	12	40	176	34	30	20	3	Drop	10.00	Sand.	
Fargo, N. D.	12	40	58	20	20	20	8	Drop	10.00	Sand, gravel.	Driving, handling.
Pittsburgh, Pa.	12	40	400	Sp.	50	33	12	Drop	14.80	Heavy clay.	Inexperienced crew.
Brownsville, Pa.	12	40	335	25	20	60	8	Drop	3.90	Sand, clay, hardpan.	Price paid contractor.
Brownsville, Pa.	12	40	77	45	44	20	15	Drop	15.00	Sand, clay, hardpan.	
Waukegan, Ill.	12	40	17	14	10	10	6	Drop	11.40	Sand, gravel, hard clay.	Labor, equipment, etc.
Chicago, Ill.	15	54	810	65	9	..	..	Steam	10.00	Silt clay.	Handling cost, 13.6 ct.
Omaha, Neb.	15	44	85	30	14	30	10	Drop	6.50	Slag, quicksand.	
Inglis, Fla.	12	29	70	20	16	26	2	Drop	16.00	6 ft. into sandstone.	
West Point, Ky.	12	33	120	37	15	25	1	Drop	30.00	Mud, clay, gravel.	Price paid contractor.
Berrien Springs, Mich.	15	41	900	30	30	35	14	Steam	11.00	Mud, sand, clay.	Difficult job.
Rock Island, Ill.	15	41	21	17	16	15	12	Drop	14.50	Gravel, hardpan.	Labor handling.
New York, N. Y.	15	38	75	15	15	..	..	Drop	20.00	Earth, sand, gravel.	
Preston Park, Pa.	15	39	142	40	34	22	8	Drop	5.33	Decayed vegetation, clay.	Price paid contractor.
Evansville, Ind.	10	28	26	14	12	35	25	Drop	7.50	Clay, shale, cobbles.	
Tomahawk, Wis.	15	45	148	22	16	16	2	Drop	20.00	Very hard driving up to 290 blows per ft.	

as a tamper to compress the concrete below the cylinder into the ground to form an enlarged bearing foot or "pedestal."

It is evident that in soft, water bearing ground or in ground below water the above methods cannot be used or, if used in very soft ground, there cannot be any certainty that a perfect pile has been made, and the result at best must be doubtful. Such conditions are met satisfactorily and well by the Raymond method.

Fig. 249. Two Views of the Foot of an Experimental Pedestal Pile. The large Irregular Projection Is a Stone which Was Cemented into the Foot.

Raymond System of Concrete Piling. Of the two classes of concrete piles, pre-cast and cast in place, this system is the only method of the cast in place class wherein a permanent form is provided for each pile.

This system consists of a collapsible steel mandrel or core tapering from 8 inches in diameter at the point, at the rate of .4 inch per ft. in length, until in a length of 37 ft. the diameter is 23.2 inches. Upon this expanded mandrel or core is placed a spirally re-inforced sheet metal shell, the reinforcement of which is grooved into the metal on 3 inch centers and for the entire length of the core or pile. This reinforcement provides rigidity to the shell and renders it capable of withstanding very severe soil pressure. It also prevents foreign substances from entering into the green concrete.

The combined mandrel and shell is driven into the ground to the point of refusal; the mandrel is then collapsed and withdrawn from the shell leaving a permanent form for the pile. The shell is then inspected on the inside and if in perfect condition from tip to top is filled with concrete and completed.

The extreme taper of the shell, combined with the friction between the shell and the surrounding soil increases the carrying capacity of the pile. The safe load on a Raymond pile varies from 25 to 30 tons.

The John Simmons Co. are supplying sectional casings in lengths of 4 ft. to 20 ft. The sections are fitted together as the

Fig. 250. Raymond Piling.

driving proceeds by means of an interior sleeve; the pile may be driven with a cast point, or if without a point the dirt or sand may be jetted out, the concrete in either case being poured in when the pile has reached the required depth. The particular advantage of this pile is that it can be used where the head room is limited.

Cast piles may be made in any section, circular, square, tri-

angular, or corrugated. They are reinforced with bars or mesh or with bars and mesh, or with bars and hoops or even with built-up sections, as I-beams; in short, piles are reinforced just as columns. They are driven in the same way as are wooden piles.

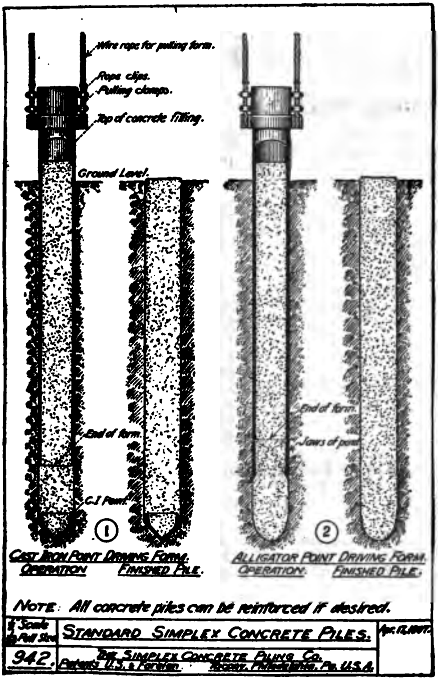


Fig. 251.

Piles are cast in horizontal molds like beams, or in vertical molds like columns. They are allowed to set hard before forms are removed and to harden thoroughly for 30 days before being driven. Often an iron pipe is molded in the pile at its center throughout its length for use of a water jet to help in the driving.

SECTION 67

PIPE

Standard Steel Pipe — Black and Galvanized

Size	Weight per ft.	List price per ft.
½	.850	$0.085
¾	1.130	.115
1	1.678	.170
1¼	2.272	.230
1½	2.717	.275
2	3.652	.370
2½	5.793	.585
3	7.575	.765
4	9.109	1.090
5	10.790	1.480
6	14 617	1.920
7	18.974	2.380
8	24.696	2.500
9	33.907	3.450
10	40.483	4.120
11	45.557	4.630
12	49.562	5.070

Discounts to apply to the above are as follows:

Size	Black	Galvanized
½	36%	19%
¾ to 3	40	24
3½ to 6	35	20
7 to 12	25	8

Cast Iron Pipe, during the first part of 1920, is quoted in New York as follows:

4 in., price per net ton in carload lots $65.30
6 in., and over 62.30
Gaspipe and 16 ft. lengths are $2 per ton extra.

The above weights are per length to lay 12 feet, including standard sockets; proportionate allowance to be made for any variation.

Clay Drain Tile. The following are the prices per 1,000 lin. ft. quoted in New York Jan., 1920.

Size in in.	Approximate weight per 1,000 ft.	Price per 1000 ft.
3	4,000	$ 35
4	7,000	51
5	10,000	65
6	13,000	90
8	19,000	130

Standard Thickness and Weights of Cast Iron Pipe Classes A, B, C, D

Classes A, B, C, D.

Nominal Inside Diam. (In.)	Class A (100-Feet Head, 43 Lb. Pressure) Thickness In.	Class A Weight per Foot	Class A Weight per Length	Class B (200-Feet Head, 86 Lb. Pressure) Thickness In.	Class B Weight per Foot	Class B Weight per Length	Class C (300-Feet Head, 130 Lb. Pressure) Thickness In.	Class C Weight per Foot	Class C Weight per Length	Class D (400-Feet Head, 173 Lb. Pressure) Thickness In.	Class D Weight per Foot	Class D Weight per Length	Nominal Inside Diam. (In.)
4	.42	20.0	240	.45	21.7	260	.48	23.3	280	.52	25.0	300	4
6	.44	30.8	370	.48	33.3	400	.51	35.8	430	.55	38.3	460	6
8	.46	42.9	515	.51	47.5	570	.56	52.1	625	.60	55.8	670	8
10	.50	57.1	685	.57	63.8	765	.62	70.8	850	.68	76.7	920	10
12	.54	72.5	870	.62	82.1	985	.68	91.7	1100	.75	100.0	1200	12
14	.57	89.6	1075	.66	102.5	1230	.74	116.7	1400	.82	129.2	1550	14
16	.60	108.3	1300	.70	125.0	1500	.80	143.8	1725	.89	158.3	1900	16
18	.64	129.2	1550	.75	150.0	1800	.87	175.0	2100	.96	191.7	2300	18
20	.67	150.0	1800	.80	175.0	2100	.92	208.3	2500	1.03	229.2	2750	20
24	.76	204.2	2450	.89	233.3	2800	1.04	279.2	3350	1.16	306.7	3680	24
30	.88	291.7	3500	1.03	333.3	4000	1.20	400.0	4800	1.37	450.0	5400	30
36	.99	391.7	4700	1.15	454.2	5450	1.36	545.8	6550	1.58	625.0	7500	36
42	1.10	512.5	6150	1.28	591.7	7100	1.54	716.7	8600	1.78	825.0	9900	42
48	1.26	666.7	8000	1.42	750.0	9000	1.71	908.3	10900	1.96	1050.0	12600	48
54	1.35	800.0	9600	1.55	933.3	11200	1.90	1141.7	13700	2.23	1341.7	16100	54
60	1.39	916.7	11000	1.67	1104.2	13250	2.00	1341.7	16100	2.38	158.3	19000	60
72	1.62	1283.4	15400	1.95	1545.8	18550	2.39	1904.2	22850	...	.....	.....	72
84	1.72	1633.4	19600	2.22	2104.2	25250	...	.....	.....	...	.....	.....	84

The above weights are per length to lay 12 feet, including standard sockets; proportionate allowance to be made for any variation.

Sewer Pipe. The following prices are per ft. quoted in New York Jan., 1920.

Calibre, Inches.	Thickness, Inches.	Weight per Foot, Pounds.	Depth of Sockets, Inches.	Annular Space, Inches.	Av. Price per Foot.
3	½	7	1½	¼	$0.09
4	½	9	1⅝	⅜	.09
5	⅝	12	1¾	⅜	.135
6	⅝	15	1⅞	⅜	.135
8	¾	23	2	⅜	.210
9	13/16	28	2	⅜	.260
10	⅞	35	2⅛	⅜	.315
12	1	45	2¼	½	.405
15	1⅛	60	2½	½	.540
18	1¼	85	2¾	½	.750
20	1⅜	100	3	½	.900
21	1½	120	3	½	1.050
22	1½	130	3	½	1.200
24	1⅝	150	3¼	½	1.350
27	2	224	4	¾	2.145
30	2⅛	250	4	¾	2.376
33	2¼	310	5	1¼	3.150
36	2½	350	5	1¼	3.588

Cost of Pipe Laying. The following is from my notes in 1914. The cost per linear foot of pipe laid depends upon the kind of pipe, involving its weight, size and mode of lowering into the trench, on the depth of the trench and obstructions to lowering due to sheeting, etc., on the kind of joint, whether bitumen, lead or cement, and on the directorship of the foreman and the skill of the workmen. As in the case of sheeting, pipe laying requires skilful workmen. Men should be carefully trained to do this work and should then be kept at it.

Unit Costs for Small Pipe. In Table 1 will be found unit costs and other data on 6, 8, 10 and 12-in. sanitary sewer pipe. This pipe was vitrified salt-glazed clay pipe, and had joints first calked with oakum and then filled with hot bitumen. Two or three lengths of pipe were joined together on the surface of the ground, the hub and spigot being first cleaned of any foreign substances by washing with a solution of bitumen dissolved in gasoline. The joints were next calked with oakum and then, with the pipes in an upright position, the joints were filled with melted bitumen. When the joints were cool and firm, a rope having a hook on one end was placed through the pipes and hooked to the lower edge, in which position the pipes were lowered. Another method of lowering was to pass a rope through the pipes so that both ends might be grasped by men on the surface and the pipes lowered horizontally. The lowering and, in fact, the laying were retarded greatly by the braces which held the sheeting, and also by the great depths of trench.

After a section was lowered into the trench and properly lined

TABLE 1 — UNIT COSTS (1914) AND OTHER DATA FOR LAYING VITRIFIED SANITARY SEWER PIPE, SIZES 6, 8, 10 AND 12 IN.

No. Obs.	Unit cost, cents per lin. ft.	Cut, ft.	No. men	Size of pipe, in.	Equivalent 10-hr. performance, lin. ft.	Quantity per joint, lb. Tar	Oakum	Remarks
					Case 1			
1	2.7	6.5	5	6	310			
2	4.9	6.5	5	6	261			Sheeting
3	5.2	6.5	5	6	310			
Av. ..	4.3	6.5	5	6	293.6			
					Case 2			
1	4.0	6	5	8	424			
2	5.2	8	6	8	310	0.80	0.20	Sheeting
3	5.4	8	4	8	171	0.82	0.24	Sheeting
4	6.0	8.4	4	8	141			Sheeting
5	6.0	7	6	8	210			Sheeting
6	6.26	8	5	8	198	0.91	0.23	Sheeting
7 ...	6.3	8.7	5	8	179			Sheeting
8	6.4	8	4	8	144	0.95	0.28	Sheeting
9	6.45	8	5	8	128	0.82	0.24	Sheeting
10	6.46	8	5	8	189	0.70	0.20	Sheeting
11	6.6	8	4	8	127			Sheeting
12	6.6	8	4	8	149	0.94	0.27	Sheeting
13	7.05	6.5	5	8	152			Sheeting
14	7.1	6	5	8	150			Sheeting
15	7.2	9	4	8	106	0.66	0.26	Sheeting
16	7.35	8	6	8	224	0.81	0.27	Sheeting
17	7.90	8	4	8	132	0.87	0.22	Sheeting
18	8.5	8	6	8	135	0.67	0.17	Sheeting
19	9.1	8	4	8	92	0.65	0.35	Sheeting
20	9.35	7	5	8	163			Sheeting
21	9.7	8	4	8	80	0.60	0.15	Sheeting
22	9.85	9	4	8	88	0.63	0.31	Sheeting
23	10.90	8	4	8	57	0.79	0.21	Sheeting
24	11.4	9	4	8	59	0.84	0.17	Sheeting
25	13.5	8	4	8	63			
Av. ..	7.6	7.9	4.6	8	152.4	0.78	0.235	
					Case 3			
1	5.7	9	3	10	210			Solid Sheeting
2	7.5	10	3	10	136			Solid Sheeting
3	7.8	10	4	10	160			Solid Sheeting
4	9.1	8.5	4	10	136			Solid sheeting
Av. ..	7.5	9.4	3.5	10	160.5			
					Case 4			
1	5.4	8	5	12	189			Sheeting
2	5.7	7	5	12	228			Sheeting
3	6.0	8	5	12	178			Sheeting
4	6.4	8	5	12	207			Sheeting
5	7.4	7	5	12	152			Sheeting
6	8.0	10.5	5	12	132			Sheeting
7	8.1	7.5	5	12	137			Sheeting
8	8.7	15	4	12	63			Sheeting
9	9.4	7	5	12	110			Sheeting
10	10.2	8	4	12	71			Sheeting
11	10.8	10	5	12	83	1.72	0.69	Solid sheeting
12	11.5	11	5	12	77	1.56	0.62	Solid sheeting
13	11.6	13	5	12	60	1.43	0.44	Solid sheeting
14	11.9	10	5	12	74	0.96	0.19	Solid sheeting

No. Obs.	Unit cost, cents per lin. ft.	Cut, ft.	No. men	Size of pipe, in.	Equivalent 10-hr. performance, lin. ft.	Quantity per joint, lb. Tar	Oakum	Remarks
15	12.0	17	4	12	52			Solid sheeting
16	12.4	10	5	12	67	1.34	0.54	Solid sheeting
17	13.0	12	5	12	66	1.00	0.25	Solid sheeting
18	13.7	10	5	12	62	1.59	0.54	Solid sheeting
19	13.75	13	4	12	64	0.87	0.22	Solid sheeting
20	13.80	10	5	12	60	0.83	0.17	Solid sheeting
21	14.4	14	6	12	90	1.13	0.45	Solid sheeting
22	16.0	13	5	12	52	2.38	0.71	Solid sheeting
23	16.3	13	5	12	50	1.18	0.35	Solid sheeting
24	17.6	13	4	12	35	1.54	0.31	Solid sheeting
Av.	11.0	10.6	5	12	98.3	1.35	0.42	

TABLE 2 — UNIT COSTS (1914) AND OTHER DATA FOR STORM DRAINS, SIZES 12, 15, 24 AND 36 IN.

No. Obs.	Unit cost, ct. per lin. ft.	Cut, ft.	No. men	Size of pipe, in.*	Equivalent 10-hr. performance, lin. ft.	Per joint, lb. cement	Remarks
				Case 5			
1	2.8	6	4	12 C	300	3.33	No sheeting
2	2.9	7	4	12 C	268	3.80	No sheeting
3	3.2	5	3	12 V	220	2.8	No sheeting
4	3.4	6	4	12 C	240	4.18	No sheeting
5	3.4	6	4	12 C	261	2.61	No sheeting
6	3.52	5.5	3	12 V	198	1.98	No sheeting
7	3.6	6	3	12 V	250	4.1	No sheeting
8	3.7	6	4	12 C	250		No sheeting
9	3.7	5	3	12 V	232	4.76	No sheeting
10	3.8	5.7	4	12 C	240		Very little sheeting
11	3.8	5	3	12 V	232	4.66	No sheeting
12	3.9	6.5	2	12 V	130	4.18	No sheeting
13	4.6	6	3	12 V	152	3.58	No sheeting
14	4.7	6	3	12 V	119	3.78	No sheeting
15	5.27	7	5	12 C	190	3.54	No sheeting
16	6.70	6	4	12 C	120		No sheeting
17	8.2	6	4	12 C	125	2.00	No sheeting
Average	4.2	6.0	3.5	12	209	3.52	
				Case 6			
1	3.6	7	5	15 C	260		Sheeting
2	5.0	6	5	15 C	204	4.4	Sheeting
3	5.25	8	4	15 C	165	4.5	Sheeting
4	6.70	8	5	15 C	150	4.0	Sheeting
Average	5.14	7.25	5	15 C	194.7	4.3	
				Case 7			
1	6.35	7	5	24 C	157		Sheeting
2	6.80	7	6	24 C	162	1.85	Sheeting
3	6.90	7	5	24 C	144		Sheeting
4	7.85	7.25	5	24 C	131		Sheeting
5	8.35	7	7	24 C	162	2.46	Sheeting
6	9.1	9.5	6	24 C	126		Sheeting
7	9.4	8.5	6	24 C	122		Sheeting

No. Obs.	Unit cost, cents per lin. ft.	Cut, ft.	No. men	Size of pipe, in.	Equivalent 10 hr. performance, lin ft.	Quantity per joint, lb. Tar	Oakum	Remarks
8	12.0		12	5	24 C	81		Sheeting
9	12.3		8	4	24 C	75.5		Sheeting
10	13.2		6.5	5	24 C	75		Sheeting
†11	23.6		8	4	24 C	41		No sheeting
Average	9.2		8.0	5.4	24 C	123.5	2.15	
					Case 8		Mixing and placing concrete base, cents per lin. ft.	
1	9.8		9	4	36 V	86	11.5	Solid sheeting
2	12.9		9	4	36 V	77.5	17.9	Solid sheeting
3	16.9		9	5	36 V	68	21.2	Solid sheeting
4	18.1		9	5	36 V	56	18.9	Solid sheeting
5	20.0		9	4	36 V	64		Solid sheeting
Average	15.5		9	4		70	17.4	

* 12 C = 12-in. circular concrete pipe.
12 V = 12-in. circular vitrified pipe.
15 C = 15 in. egg-shaped concrete pipe.
24 C = 24 in. egg shaped concrete pipe.
36 V = 36 in. circular vitrified pipe.
† Left out of the averages.
Average widths of trench, 12-in. pipe, 36 in.; 15-in., 30 in.; 24-in., 42 in.; 36 in., 60 in.
In the above unit costs cementing the pipe joints is included with the laying, also a proportion of the charges for foreman and waterboy.

in both horizontal and vertical planes the joint was calked with oakum and filled with bitumen, using a "snake" in the same manner that a leaded joint is run. One man on top was in charge of jointing, and another man was responsible for supplying the men in the trench with hot tar, also assisting in lowering the pipe. When not so engaged he should assist the first man to prepare the pipe. A third man was needed to assist in lowering. In the trench one regular man and an assistant had charge of the jointing and alignment. When not so engaged they made grade for the next two lengths, using the material thus removed for backfill over the pipes last laid.

Unit Costs for Large Pipe. In Table 2 will be found unit costs and other data on storm-water sewer pipes, 12, 15, 24 and 36 in. in diameter. All joints were cemented after the pipe was lowered into the trench in single lengths. The 12-in. pipe was of circular section, some cement and some vitrified. Lowering was done by hand, using a rope passed through the length of the pipe.

The 15 and 24-in pipe used in the work were made of cement and were egg-shaped. To lower these into the trench a tripod rigged with a differential block and tackle was used. The 36-in.

pipe was vitrified and circular in section. A tripod and a block were also used here in lowering.

Average widths of trench, 6-in. pipe, 30 in.; 8-in., 32 in.; 10-in., 36 in.; 12-in., 36 in.

In the above unit costs are included the cost of preparing pipe, laying, calking and tarring, and a proportion of the charges for foreman and waterboy.

SECTION 68

EQUATION OF PIPES

Standard Steam and Gas Pipes

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12
½		2.27	4.88	15.8	31.7	52.9	96.9	205	377	620	918	1,292	1,767	2,488	3,014	3,786
¾	2.60		2.05	6.97	14.0	23.3	42.5	90.4	166	273	405	569	779	1,096	1,328	1,668
1	7.55	2.90		3.45	6.82	11.4	20.9	44.1	81.1	133	198	278	380	536	649	815
1½	24.2	9.30	3.20		1.26	3.34	6.13	13.0	23.8	39.2	58.1	81.7	112	157	190	239
2	54.8	21.0	7.25	2.26		1.67	3.06	6.47	11.9	19.6	29.0	40.8	55.8	78.5	95.1	119
2½	102	39.4	13.6	4.23	1.87		1.83	3.87	7.12	11.7	17.4	24.4	33.4	47.0	56.9	71.5
3	170	65.4	22.6	7.03	3.11	1.66		2.12	3.89	6.39	9.48	13.3	20.9	23.7	31.2	39.1
4	376	144	49.8	15.5	6.87	3.67	2.21		1.84	3.02	4.48	6.30	8.61	12.1	14.7	18.5
5	686	263	90.9	28.3	12.5	6.70	4.03	1.83		1.65	2.44	3.43	4.69	6.60	8.0	10.0
6	1,116	429	148	46.0	20.4	10.9	6.56	2.97	1.63		1.48	2.09	2.85	4.02	4.86	6.11
7	1,707	656	226	70.5	31.2	16.6	10.0	4.54	2.49	1.51		1.41	1.93	2.71	3.28	4.12
8	2,435	936	322	101	44.5	23.8	14.3	6.48	3.54	2.18	1.43		1.35	1.93	2.33	2.92
9	3,335	1,281	440	137	60.8	32.5	19.5	8.85	4.85	2.98	1.95	1.37		1.41	1.71	2.14
10	4,393	1,688	582	181	80.4	42.9	25.8	11.7	6.40	3.93	2.57	1.80	1.32		1.21	1.52
11	5,642	2,168	747	233	103	55.1	33.1	15.0	8.22	5.05	3.31	2.32	1.70	1.28		1.26
12	7,087	2,723	938	293	129	69.2	41.6	18.8	10.3	6.34	4.15	2.91	2.13	1.61	1.26	

This table gives the number of pipes of one size required to equal in delivery other larger pipes of same length and under same conditions. The upper portion above the diagonal line pertains to "Standard" steam and gas pipes, while the lower portion is for pipes of the actual internal diameter given. The figure given in the table opposite the intersection of any two sizes is the number of the smaller sized pipes required to equal one of the larger. Thus, it requires 29 standard 2 inch pipes to equal one standard 7 inch pipe.

SECTION 69

PIPE LINE TOOLS

Lead Melting Furnace, pot, bar, grate and ladle on two wheels with handle and stand. Of heavy boiler plate with wrought iron wheels.

Capacity in lb.	Price On wheels	Price On legs
200	$48	$33
450	57	40
700	73	50

A Gasoline Lead Melting Furnace having a capacity of 200 lb., costs $52; capacity of 325 lb., $54.

Calking Hammers, 3 lb., $1.00; 4 lb., $1.25 handled.

Calking Tools, set of 5 tools and yarning iron, weight 9 lb., price 40c per lb.

Lead Wool Tools, cost 50c per lb.

Dog Diamonds, 4 lb., $1.75.

Dog Chisels, 2½, 3, 3½ and 4 lb., 40c per lb.

Hand Chisels, ⅞ octagon steel, 40c per lb.

Hand Diamond Points, ⅞ octagon steel, 40c per lb.

Bursting Wedges, 8 in. long, 1½ to 2 lb., 30c per lb.

Asbestos Joint Runners, range from $2.40 for the ¾ in. square for 4, 5 and 6 in. pipe, to $14.40 for the 1¼ in. square for 48 in. pipe.

Pipe Jointers cost from $3.30 for 4 inch pipe to $9.50 for 20 inch pipe.

Sewer Builders Mauls of hickory having a diameter of 7 in. and 12 in. in length weigh about 24 lb. and cost $4.00 each.

Steel Plank Caps. Box caps 2 by 6 and 2 by 8 in. cost $2.75 each. Open end caps 2 by 6 in. cost $2.00 and 2 by 8 in. cost $2.50 each.

Plank Puller of cast steel, for 2 in. plank $5.00, 3 in. plank $7.00.

Trench Braces with 1½ inch pipe barrels and 1¼ in. screws extend safely 10 in. are made up to 3 ft. 6 in. length. The longer braces have 2 in. pipe barrels and 1½ in. screw, and extend safely 13 in.

Length when closed	Weight in lb. per doz.	Price per doz.
1 ft. 6 in.	146	$17.10
2	162	18.00
2 6	178	18.90
3	194	19.80
3 6	210	20.80
4	321	26.00
4 6	353	27.00
5	375	28.00
5 6	397	29.00
6	419	30.00
6 6	441	31.00

All the foregoing prices are f. o. b. New York.

Fig. 252. Laying 48-in. Water Main at Buffalo, N. Y. Width of Cut 5½ ft. Size of Brace Used 4½ ft. (Closed).

SECTION 70

PLANT RENTAL CHARGES

The following list of rental charges for construction equipment was submitted by an eastern contractor. It is taken from an article in *Engineering and Contracting*, Jan. 21, 1920.

Equipment	Weekly rental
Boiler, only, 30 hp. and smaller	$12.00
Boiler only, 30 to 60 hp.	16.00
Bucket, clamshell, ¾-yd.	15.00
Cars, skip, 1½-yd.	2.00
Cars, steel, 1-yd. and smaller	1.50
Crusher only, Acme No. 9½	22.00
Cutter, bar portable, with motor	9.50
Derrick, 30 to 59 ft., wooden, home made	3.00
Drill, small air	3.00
Drill, steam	4.50
Elevator, platform or bucket, 1 yd.	2.00
Engine, skeleton, 2-drum, 20 hp.	8.00
Engine, gasoline, to 8 hp.	3.00
Engine, gasoline, 10 hp.	5.00
Leveling instrument, engineers'	1.50
Mixers, with gasoline engine, 11 to 15 ft. cap.	15.00
Motors, 2 hp.	1.50
Motors, 5 hp.	2.50
Motors, 10 hp.	3.50
Motors, 25 hp.	5.00
Motors, 50 hp.	9.00
Pumps, centrifugal, 10-in., belt driven, with engine	7.00
Pumps, pulsometer, to 4-in.	6.00
Pumps, 3-in., with gasoline engine	3.50
Pumps, diaphragm, with gasoline engine	3.50
Saw benches, plain	3.00
Saw benches, plain, with motor or gas engine attached	5.50
Saw swing cutoff, no power	1.00
Steam shovels, revolving, traction, per day	24.00
Transit	2.00

In submitting the list, the contractor wrote as follows concerning his firm's policy on equipment rental:

The plant rental sheet was revised the first of this year and will be revised again for another year, probably upwards. Our rental basis for our own work is entirely that of replacement cost. All plant costing $150 or more whose life extends over a period of years or over several jobs is shown on our detailed list, which is compiled from our experience of the probable life of each tool. There are three classes:

Class A — Tools which will last through 50 weeks of continuous work.

Class B — Tools which will last through 75 weeks of continuous work.

Class C — Tools which will last through 100 weeks of continuous work.

Our rental is sufficient to produce enough revenue to make extraordinary repairs and to replace the plant at the end of this length of time.

You will find that these rentals are uniformly low because they are at cost to ourselves and apply on jobs where we are operating the plant. These plant rentals go into a costplus or fixed-fee contract as a part of the job cost on which profit is figured.

If we rented the plant to outsiders we would charge about half as much again for it.

Our method of handling small tools such as shovels, picks, hammers, etc., is to charge their entire cost to the job. If they are worn out they become part of the job cost. At the completion of the work an inventory is taken and each tool is appraised in co-operation with a representative of the owner. We have five grades: (1) New, 100% of first cost; (2) good, 75%; (3) fair, 50%; (4) poor, 25%; (5) worthless, 0%. We take them back as per inventory.

The following notes and table of rental values of construction equipment are from an article by Mr. F. J. Herlihy in *Engineering News Record*, Jan. 15, 1920.

The cost to the contractor of owning equipment may be broadly defined as comprising: 1, capital investment; 2, interest on capital investment; 3, insurance; and 4, storage expense during idle time.

The column in the table headed Original Capital Cost is intended to show typical results only and is given as a basis on which the details of plant rental (both costs and percentages) are worked out.

In actual practice the true first cost of the equipment should be substituted for that shown in the table and the analysis worked out accordingly, using as the other factors, the fixed percentages shown. Where the contractor owns several machines of the same class, size and type, which cost different prices, the average original cost should be used. Average depreciation only is considered in fixing the various factors of accrued costs, and charges shown in the table as depreciation will vary for the different makes of equipment on the same class of work and will be dependent more or less on the nature of the work for all classes of equipment. Average equipment working under ordinary condi-

tions, covering the entire time the contractor may be in business, is considered. The figures shown in the table for repair items are based on present prices and average conditions. They will vary with the fluctuation of the labor and material market and with the different makes of equipment, depending more or less on the character of the work and the manner in which the equipment is handled. The percentage rate of depreciation and the average earning days per annum are quantities that experience alone can measure, a perusal of the records of contractors who have been using the class of equipment under consideration for an appreciable time being the only source of information. The factors used in the table for depreciation, average earning days per annum, and shop and field repairs show the writer's conclusions of their values based on his general experience, a perusal of extensive data on the subject and the records of a large grading contractor. Additional information was secured from several months' attendance at arbitration proceedings in which more than $600,000 worth of rental charges on equipment, similar to that shown in the table, were part of the issue. Several weeks were spent on the principles and rates of rental exclusively, and much expert testimony was adduced by both sides. The finding of the arbitrators, while not allowing all rental claimed for other reasons, approved the rates of rental contended for and the principles thereof in most instances. The rental rates in that case were based on practically the same percentages and principles as those ir the table shown here, the cost of repairs being practically the only departure. As the rental factors in that case were based on pre-war conditions, this departure is necessary to bring the cost of these items into conformity with present values. Proceeding to analyze the different cost elements, we have: —

Different Cost Elements. *Original Capital Cost.* This element represents the first cost of the equipment which must be recovered by charging off the depreciation periodically and from the proceeds of its sale at the end of its useful life. In fixing the annual rate of depreciation (average between idle and working time) due credit has been given the first cost of the equipment for its scrap or obsolescent value. The rate shown represents simply the rate of depreciation reduced to terms of original cost, which, if applied annually, against the first cost, will take care of the difference between first cost and the sale price at the end of the useful life. Obsolescence is considered as being reached with any piece of equipment when it must be discarded for one that will do the work more economically.

Interest on Capital Investment. The rate shown in the table represents the rate, which, if applied annually against the first

cost of the equipment, will take care of interest charges against the capital investment throughout the useful life of the equipment at the customary rate of 6% per annum on the average capital value. Assuming the sale price of the equipment at the end of the useful life at 25% of the first cost, this makes the average capital value of the equipment 62½% of the first cost. For machines which have no sale value at the end of the useful life this becomes 50% of the first cost.

Insurance and Storage During Idle Time. These two items of expense have been combined in the table because they are more or less related and the insurance item is less than 1% per annum of the original capital cost. The charge for these elements of cost include interest, depreciation, and maintenance of storage facilities, and all expense incurred for the storage of equipment. It also includes the expense of insurance on storage facilities and construction equipment. The annual percentage rate shown in the table is based on an annual cost of $15,000 to cover these items of expense on a construction plant the first cost of which was $400,000.

The columns headed "Rate of accrued charges on original cost" and "Total annual charge" in the table sum up the percentage and money charge respectively, that must be applied annually against the first cost of each piece of equipment. These columns simply sum up the interest, depreciation, insurance and storage items just described. The values in the column headed "Total annual charge" will vary with the original capital cost, but those shown in the percentage column will remain constant and they are the key to finding the actual annual charge to be made in all cases.

Having arrived at the annual cost to the contractor of owning the equipment, the next thing to ascertain is how to apply the charge against the different contracts in order to come out whole. In making this application, it is necessary to understand that there is of necessity a certain amount of idle time between contracts during which the contractor has no work against which to apply the accrued costs of owning the equipment, and that contractors engage in the contracting business to stay indefinitely. It naturally follows that the contractor must carry on hand at all times enough equipment to enable him to bid on work with a certainty that he can equip the work in the time provided for by the specifications. The contractor, therefore, who fails to include charges in his plant rental rate during the earning time of the equipment that will absorb the accrued costs during the idle time between contracts upsets the very foundations of sound business principles and faces inevitable losses, either by way of being forced to dispose of the equipment quickly at the best price ob-

tainable, or by assuming the accrued costs of holding it during the idle time between contracts. Of course, there is the alternative of renting the equipment during the idle time but that too has its uncertainties, as a renter will not always be available If these premises are correct the number of earning days, or the number of calendar days on which the equipment is assigned to work per annum is the factor to apply to the total annual charge in arriving at the correct daily rental charge to be made against the work. By this method, the total accrued costs of owning the equipment is absorbed by the earning time of the equipment and the enforced idle costs properly accounted for. The average number of earning days per year for the different classes of equipment, based on the information described at the beginning of this analysis is shown in the table. The values shown represent the number of calendar days and not actual working days intervening between the time the equipment has been shipped to the work and its return to the storage plant, or until it has been assigned to another job. In other words, rental should be charged against the work for each and every calendar day on which the equipment is assigned to the work, working days being too uncertain a factor on which to base. The column headed "Daily charge for interest, depreciation, insurance and storage" represents the values arrived at by dividing the annual charge for accrued expenses and charges by the average number of earning days per year. The rates shown in the column should be used only in making charges on work of such duration as to permit of shop and field repairs being charged directly against the work.

Maintaining Equipment in Useful Condition. Having disposed of the cost to the contractor of owning the equipment, there remains the expense of maintaining it in useful condition. This expense, as before stated, comprises the elements of general or shop repairs, and of field repairs All construction equipment must be overhauled, and renewals and major repairs, commonly designated as shop repairs, made periodically. The cost of these repairs per earning day, is shown in the table. The expense of making these repairs cannot ordinarily be charged directly against the work, as they usually accrue on several contracts. The most satisfactory method of handling them is to provide a sinking fund by charging in the rental rate an amount daily that will accumulate a fund sufficient to cover the cost of these repairs at such periods as they are required. It is this daily charge that is shown in the column headed "General shop repairs daily" in the table

Daily Rental Value Including Shop Repairs. In the column of the table headed "Daily rental" will be found the values of rental per earning day for the different classes of equipment, in-

cluding the allowance for sinking fund to take care of shop repairs. This represents the daily rental charge that should be made against each piece of equipment on ordinary work to take care of the annual charge and shop repairs. It is the values shown in this column of the table that should be used for all jobs except those which are of too short duration to allow for field repairs to be charged directly against the work and those which are long enough to allow both field and shop repairs to be charged directly against the work.

Field Repairs. Field repairs are generally charged up directly against the work. They comprise simply such minor repairs and replacements as are due to the ordinary breakage and wear of parts that must be taken care of on the job to keep the equipment running. The column headed "Est. cost field repairs daily" gives the value of these repairs per earning day.

Total Rental Charges. There is a final column in the table, headed "Total rental charges daily including field repairs" in which the daily charge shown in the column headed "Daily rental" is augmented by the addition of the field repair charge. This column is given for the information of the estimator who is concerned only with the total cost daily of equipment to the work, as his charges must also include the field repairs in making up the tender. The values in this column are also used in charging out rental on jobs of short duration where there will be practically no field repairs, thereby preventing the charging of the field repairs directly to the work.

In cases where force account jobs come up, requiring the use of equipment for short intervals of time less than weeks, it is recommended that charges be made on a working day basis instead of the earning day basis shown in the table. In this manner the lost time, including holidays will be taken care of. It will be usually found that an increase of 25% on the total rental rate including field repairs will cover this condition.

It should be kept in mind that all values shown in the table for equipment rental show actual costs and do not include any element of profit. Should the equipment be rented to outsiders a profit should be added to the above.

RENTAL RATES FOR GRADING

Class of equipment	Original capital cost	Equivalent annual interest rate on original cost, %	Annual rate of depreciation on original cost, %	Annual insurance and storage rate on original cost, %	Total annual rate of accrued charges on original cost, %
Steam shovel	$12,000	3¾	12½	3¾	20
Steam shovel	20,000	3¾	12½	3¾	20
Steam shovel	30,000	3¾	12½	3¾	20
Steam shovel	90,000	3¾	12½	3¾	20
Drag line excavator	20,000	3¾	12½	3¾	20
Drag line excavator	30,000	3¾	12½	3¾	20
Standard gage locomotive	12,000	3¾	12½	3¾	20
Standard gage locomotive	16,000	3¾	7½	3¾	15
Standard gage locomotive	24,000	3¾	7½	3¾	15
Dinkey locomotive	4,000	3¾	12½	3¾	20
Dinkey locomotive	6,000	3¾	12½	3¾	20
Locomotive crane	20,000	3¾	12½	3¾	20
Jordansreader	9,000	3¾	12½	3¾	20
Rail per ton	48	3¾	7½	3¾	15
Track throwing machine	6,000	3¾	12½	3¾	20
20-yd. air dump cars	3,750	3¾	12½	3¾	20
16-yd. air dump cars	2,800	3¾	12½	3¾	20
12-yd. air dump cars	2,000	3¾	12½	3¾	20
4-yd. dump cars	430	3¾	12½	3¾	20
1½-yd. dump cars	110	3¾	12½	3¾	20
1-yd. dump cars	90	3¾	12½	3¾	20
Flat cars	1,000	3¾	7½	3¾	15
Gasoline locomotive	3,200	3¾	12½	3¾	20
1-yd. Koppel cars, V shape	110	3¾	12½	3¾	20
Motor truck, 5-ton	6,000	3¾	22½	3¾	30
Automobile	2,000	3¾	31¼	15	50
Caterpillar tractor gas	5,000	3¾	12½	3¾	20
Vertical boiler	900	3¾	7½	3¾	15
Locomotive boiler	1,500	3¾	7½	3¾	15
Steam pump	500	3¾	7½	3¾	15
Centrifugal pump, d. c.	1,500	3¾	7½	3¾	15
Belted pump	300	3¾	7½	3¾	15
Deep well pump	600	3¾	7½	3¾	15
Gasoline engine	1,200	3¾	7½	3¾	15
Steam engine	1,800	3¾	7½	3¾	15
Hoisting engine	4,250	2¾	7½	3¾	15
Horse pile driver	800	3¾	12½	3¾	20
Steam pile driver	2,000	3¾	12½	3¾	20
Track pile driver	10,000	3¾	7½	3¾	15
Steam pile hammer	2,500	3¾	7½	3¾	15
Air compressor	3,000	3¾	7½	3¾	15
Electric motor	500	3¾	12½	3¾	20
Deep well drill	2,000	3¾	12½	3¾	20
Steam tripod drill	400	3¾	12½	3¾	20
Jack hammer drill	140	3¾	12½	3¾	20
Air steel sharpener	2,000	3¾	12½	3¾	20
Stiff leg derrick	2,000	3¾	12½	3¾	20
Forrest log loader	400	3¾	12½	3¾	20
Lee wagon loader	225	3¾	12½	3¾	20
Clam shell bucket	1,500	3¾	12½	3¾	20
Rock channeler machine	3,000	3¾	12½	3¾	20
Grading machine	1,350	3	23¼	3¾	30
Pony road grader	200	3	23¼	3¾	30
Grading plow	30	3	23¼	3¾	30

CONTRACTORS' EQUIPMENT

Total annual charge	Average earning days per year	Daily charge for int. dep. ins. and storage	General shop repairs daily	Daily rental	Estimated cost field repairs daily	Total rental daily, including field repairs
$ 2,400.00	200	$12.00	$ 4.00	$ 16.00	$ 4.00	$20.00
4,000.00	200	20.00	6.00	26.00	6.00	32.00
6,000.00	200	30.00	9.00	39.00	9.00	48.00
18,000.00	200	90.00	25.00	115.00	25.00	140.00
4,000.00	200	20.00	10.00	30.00	10.00	40.00
6,000.00	200	30.00	15.00	45.00	15.00	60.00
2,400.00	200	12.00	5.00	17.00	5.00	22.00
2,400.00	200	12.00	6.00	18.00	6.00	24.00
3,600.00	200	18.00	8.00	26.00	8.00	34.00
800.00	200	4.00	1.50	5.50	1.50	7.00
1,200.00	200	6.00	2.50	8.50	2.50	11.00
4,000.00	200	20.00	6.00	26.00	6.00	32.00
1,800.00	200	9.00	3.00	12.00	1.00	13.00
7.20	200	.04	.01	.05	.00	.05
1,200.00	200	6.00	2.00	8.00	1.00	9.00
750.00	200	3.75	.25	4.00	.25	4.25
560.00	200	2.80	.20	3.00	.25	3.25
400.00	200	2.00	.15	2.15	.15	2.30
86.00	200	.43	.07	.50	.10	.60
22.00	200	.11	.09	.20	.10	.30
18.00	200	.09	.06	.15	.10	.25
150.00	200	.75	.15	.90	.10	1.00
640.00	200	3.20	1.05	4.25	1.25	5.50
22.00	200	.11	.04	.15	.05	.20
1,800.00	200	9.00	7.50	16.50	5.00	21.50
1,000.00	200	5.00	2.50	7.50	2.50	10.00
1,000.00	150	6.66	8.34	15.00	5.00	20.00
135.00	100	1.35	.65	2.00	.00	2.00
225.00	100	2.25	1.00	3.25	.00	3.25
75.00	100	.75	.50	1.25	.00	1.25
225.00	100	2.25	1.25	3.50	.50	4.00
45.00	100	.45	.30	.75	.00	.75
90.00	100	.90	.60	1.50	.00	1.50
180.00	100	1.80	.60	2.40	.10	2.50
270.00	100	2.70	.90	3.60	.15	3.75
637.50	100	6.38	2.12	8.50	.50	9.00
160.00	100	1.60	.40	2.00	.00	2.00
400.00	100	4.00	.75	4.75	.75	5.50
1,500.00	100	15.00	3.00	18.00	2.00	20.00
375.00	100	3.75	.75	4.50	.50	5.00
450.00	100	4.50	1.50	6.00	.50	6.50
100.00	100	1.00	.35	1.35	.15	1.50
400.00	100	4.00	.50	4.50	.50	5.00
80.00	100	.80	.20	1.00	.25	1.25
28.00	100	.28	.22	.50	.25	.75
400.00	100	4.00	.25	4.25	.25	4.50
400.00	100	4.00	.50	4.50	.75	5.25
80.00	100	.80	.20	1.00	.25	1.25
45.00	100	.45	.15	.60	.15	.75
300.00	100	3.00	.25	3.25	.25	3.50
600.00	100	6.00	2.00	8.00	1.00	9.00
405.00	150	2.70	1.30	4.00	1.00	5.00
60.00	150	.40	.20	.60	.15	.75
9.00	150	.06	.04	.10	.00	.10

Class of Equipment

Class of equipment	Original capital cost	Equivalent annual interest rate on original cost, %	Annual rate of depreciation on original cost, %	Annual insurance and storage rate on original cost, %	Total annual rate of a u c r u e d charges on original cost, %
Dump wagon	180	3	23¼	3¾	30
Hauling wagons	120	3	23¼	3¾	30
Wheel scrapers	50	3	33¼	3¾	40
Slip scrapers	8	3	43¼	3¾	50
Fresno	22	3	43¼	3¾	50
Switches complete	150	3¾	7½	3¾	15
2-in. galv. pipe per 100 ft.	22	3¾	7½	3¾	15
2½-in. galv. pipe p. 100 ft.	34	3¾	7½	3¾	15
3-in. galv. pipe per 100 ft.	45	3¾	7½	3¾	15

Total annual charge	Average earning days per year	Daily charge for int. dep. ins. and storage	General shop repairs daily	Daily rental	Estimated cost field repairs daily	Total rental daily, including field repairs
54.00	150	.36	.34	.70	.15	.85
36.00	150	.24	.21	.45	.15	.60
20.00	150	.13	.12	.25	.00	.25
4.00	150	.03	.02	.05	.00	.05
11.00	150	.07	.08	.15	.00	.15
22.50	200	.11	.02	.13	.00	.13
3.30	200	.02	.01	.03	.00	.03
5.10	200	.03	.01	.04	.00	.04
6.75	200	.04	.01	.05	.00	.05

SECTION 71

PLOWS

Railroad or Grading Plows

Number of horses	Weight in lb.	Price f. o. b. factory
2	180	$32
2–4	200	40
4–6	270	46
6–8	350	56

All Steel Rooter Plows to be operated by from 2 to 12 horses or the equivalent tractor depending on the character of the work weigh 280 lb. and cost $50. Extra reversible points weigh 25 lb. and cost $7.

Hard Pan Rooter Plows for tearing up hard streets, cobble pavements, shaly rock, gravel, hard pan or for any work where a common plow cannot be used, cost $30 and the extra points cost $6.50.

Plows, of one make, suitable for road work are as follows:

Type	Horses	Weight in lb.	Price f. o. b. Chicago
Township	2	100	$21.75
*Railroad and township	2	150	26.75
*Railroad	4	175	31.00
*All steel road plow	2	150	26.75
*All-steel road plow	4	175	31.00
*Heavy railroad	6	230	38.75
*Heavy railroad	8	260	41.25
*Heavy railroad	10	350	43.25
*Heavy railroad	12	450	57.50
Rooter plow	4	265	30.50
Rooter plow, with extra point	6	310	54.00
Rooter plow	12	515	77.50

Plows marked with asterisk are furnished with extra share.

Wing or Ditch Plows. These plows are designed for making, cleaning and filling ditches, tile trenches and sewers. A plow for use with two or three horses costs $45.50, one for use with four to six horses costs $48.50, and one for use with from eight to ten horses costs $79.00. All prices f. o. b. Chicago.

Using Plow to Open Pavements. The following by Mr. C. A. Bryan is from *Engineering Record*, July 25, 1914. Plowing was

the method adopted to break up stone-surfaced streets in Carlisle, Pa., as the preliminary operation in the construction of a new sewerage system. The beam of the blow, which was designed to loosen the material to a depth of 12 in., was made from a well-seasoned piece of hickory, 8 in. square and 12 ft. 4 in. long. The point or ripping device was rigidly attached to one end of the

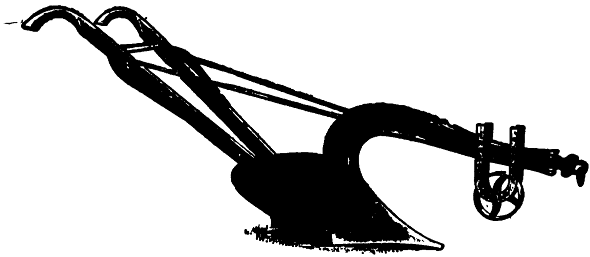


Fig. 253. Contractors' Two or Four Horse Plow.

beam, and at the other a substantial iron eye was provided through which stout chains could be passed to attach the plow to the machine that was to haul it. The point or ripper was of manganese steel 1¼ in. thick and 37½ in. long and was beveled at each end; the bevel amounted to 6 in. at each end. The point projected 8 in. in front of the cutting edge and was rigidly attached to it by steel plates ½ in. thick placed on each side of the cutting edge

Fig. 254. Rooter Plow.

and securely bolted to it by ¾-in. bolts. These same plates were similarly bolted to the point or ripper.

The cutting edge was made of a piece of steel 1¼ in. thick and 18½ in. square. The front or cutting edge was V-shaped in order to decrease the resistance of the plow in passing through the ground. As a piece it was rigidly attached to the under side of

the beam by means of two 3 x 3½ x ⅜-in. angles. The short legs of both angles were bolted to the beam by ¾-in. bolts which passed entirely through the beam, and the cutting edge was in turn bolted to the long legs of these angles by ¾-in. bolts passing through both the 1¼-in. plate and the leg of the angles. The point or ripper was thus secured about 24 in. below the beam.

To strengthen the sides of the beam a piece of band iron 6 x 60 x ½ in. was securely bolted to each side at the rear of the plow, and two narrower pieces served the same purpose at the front end. The plow was guided by means of handles.

To facilitate moving the plow from place to place a two-wheeled truck was built. This truck carried a sort of iron loop into which the point or ripper could be slipped, thus raising it

Fig. 255. Working Plow with Steam Roller.

about 6 in. above the ground and allowing the plow to be easily hauled about. An iron wheel about 6 in. in diameter was attached near the front end of the plow.

The plow was designed to be hauled behind a steam roller, to which it was attached by means of heavy iron chains. The method of operation was as follows: The center line of the sewer trench was first located by the engineer, who drove nails 50 ft. apart in the surface of the street. A line was then stretched from nail to nail and a laborer passed along it, distributing red clay as he moved. This line of clay clearly defined the center line of the ditch and acted as a guide for both the man operating the roller and the men steering the plow. A hole was then dug at one end of the block to be ripped up and made large enough to set the plow into it. The plow was put into place, the engine

attached and the plow dragged slowly along, following the center line as marked.

Generally it was found necessary to drag three or four times over the ditch in order to loosen completely the stone surfacing. In this way it was found that the stone surfacing would be loosened for a width of about 1 ft. each side of the center line of the ditch and for a depth of between 1 and 1½ ft. below the surface of the street. The gang was composed of four or five men — one man to operate the roller, two to steer the plow and one or two on the front end of the plow in order to hold it down, as it always exhibited a tendency to rise. Usually between two and three hours were required to plow up the surfacing on a block averaging 500 ft. in length.

The results obtained were very successful, as the plow left the surfacing materials so thoroughly loosened that they could be easily removed with pick and shovel. Stones fully 1 cu. ft. in size were removed by the plow. It was found that the plow would loosen almost any stone that was used in constructing a road, but it could not, of course, affect solid rock. It would also rip up without much difficulty crosswalks built of grouted paving brick. On some streets considerable difficulty was experienced, this being especially noticeable on those streets where the solid rock projected into the street surface. In one instance this resulted in the breaking of the plow beam. It was also found that the cutting edges required frequent sharpening in order to get the best results.

The accompanying table gives the estimated cost to the contractor of the work of ripping up the street surfaces on all the blocks on which this plow was used.

COSTS OF RIPPING UP PAVEMENTS WITH PLOW

Foreman, 147 hours at 25 cents	$ 36.75
Roller, including engineer, oil, fuel, etc., 210 hours at 50 cents	105.00
Labor, 450 hours at 17½ cents	78.75
Original cost of plow	55.00
Repairs (estimated)	20.00
Total cost to contractor	**$295.50**
Linear feet of street surfacing ripped up (estimated)	22,000
Estimated cost per linear foot of trench	$0.015

SECTION 72

POST HOLE DIGGERS

Post hole diggers, net prices f. o. b. St. Louis, are as follows:

	Length of blade in in.	Wt. per doz.	Price per doz.
Champion, iron handle	6	129	$18.00
Eureka, wood handles	9	112	19.00
Invincible, wood handles	10	102	22.00
Buckeye, wood handles	6½	135	30.00

Post hole augers.

	Diameter of blade in in.	Wt. per doz.	Price per doz.
Iwan pattern	6	102	$25.00
	7	111	26.20
	8	120	26.40
	9	120	28.56
	10	130	36.50
Vaughan	5 to 8	48 to 60	18.75

Fig. 256. Using Post Hole Augers to Dig Holes for Posts for Office Building, Forest Hills, N. Y.

SECTION 73

POWER

(See Boilers.)

Mr. Wm. O. Webber, a consulting engineer of Boston, has published some very interesting and most important figures to show the comparative cost of gasoline, steam, gas and electricity for small powers. His data have been compiled on the basis of yearly operation, the year comprising 3,080 hours, and for purposes of work in the Northern climate these will have to be modified to suit the special case in point. I have, however, abstracted the tables without attempting to change them.

I.— Cost of Gasoline Power (1912)

Size of plant in horsepower	2	6	10	20
Price of engine in place	$150.00	$ 325.00	$ 500.00	$ 750.00
Gasoline per B. H. P. per hour	⅓ gal.	¼ gal.	⅛ gal.	⅛ gal.
Cost per gallon	$ 0.22	$ 0.20	$ 0.19	$ 0.18
= cost per 3,080 hours	$451.53	$ 924.00	$ 975.13	$1,386.00
Attendance at $1 per day	308.00	308.00	308.00	308.00
Interest, 5%	7.50	16.25	25.00	37.50
Depreciation, 5%	7.50	16.25	25.00	37.50
Repairs, 10%	15.00	32.50	50.00	75.00
Supplies, 20%	30.00	65.00	100.00	150.00
Insurance, 2%	3.00	6.50	10.00	15.00
Taxes, 1%	1.50	3.25	5.00	7.50
Power cost	$824.03	$1,371.75	$1,498.13	$2,016.50

To these figures should be added charges on space occupied, as follows:

Value of space occupied	$100.00	$ 150.00	$ 200.00	$ 300.00
Interest, 5%	$ 5.00	$ 7.50	$ 10.00	$ 15.00
Repairs, 2%	2.00	3.00	4.00	6.00
Insurance, 1%	1.00	1.50	2.00	3.00
Taxes, 1%	1.00	1.50	2.00	3.00
Total annual charge for space	$ 9.00	$ 13.50	$ 18.00	$ 27.00
Total cost per annum	$833.03	$1,385.25	$1,516.13	$2,043.50
Cost of 1 horsepower per annum 10-hour basis	416.51	239.87	151.61	102.17
Cost of 1 horsepower per hour	0.1352	0.0780	0.0492	0.0331

II.—Cost of Electric Current (1912)

The costs for the electric current which are used in this table are figured from the discount table shown as follows:

Base price = 13½c per KW. hour. Discounts on Monthly Bill.

Monthly Bill.	Discounts.	Monthly Bill.	Discounts.
$ 5	10%	$100 to $125	40%
10 to $ 20	15%	125 to 150	45%
20 to 25	20%	150 to 175	50%
25 to 50	25%	175 to 200	55%
50 to 75	30%	200 to 500	60%
75 to 100	35%	500 and over	65%

For 2-horsepower plant:

$$\frac{3{,}080 \text{ hrs.} \times 2 \text{ hp.} \times 0.746}{82\% \text{ Effic.}} = 5{,}604.10 \text{ KW. hr. per annum}$$

then

5,604.1 × $0.135 = $756.55, annual cost without discount.
Monthly bill = $63. Discount = 30%.
$756.55 × 70% = $529.56 = Annual cost.

For 6-horsepower plant:

$$\frac{3{,}080 \text{ hrs.} \times 6 \text{ hp.} \times 0.746 \times \$0.135 \times 45\%}{86\% \text{ Effic.}} = \$976.00$$

Monthly cost = $180. Discount = 55%

For 10-horsepower plant:

$$\frac{3{,}080 \times 10 \times 0.746 \times 0.135 \times 40\%}{87\%} = \$1{,}425.00$$

Monthly cost = $298. Discount = 60%

For 20-horsepower plant:

$$\frac{3{,}080 \times 20 \times 0.746 \times 0.135 \times 35\%}{88.5\%} = \$2{,}450.00$$

Monthly cost = $585. Discount = 65%

Size of plant in hp.	2	6	10	20
Cost of motor in place	$ 83.00	$118.00	$216.00	$270.00
With wiring, etc.	100.00	130.00	240.00	300.00
Cost of electricity, 3,080 hrs.	$529.56	$ 976.00	$1,425.00	$2,450.00
Attendance	20.00	30.00	50.00	50.00
Interest, 5%	5.00	6.50	12.00	15.00
Depreciation, 10%	10.00	13.00	24.00	30.00
Repairs, 5%	5.00	6.50	12.00	15.00
Supplies, 1%	1.00	1.30	2.40	3.00
Insurance, 2%	2.00	2.60	4.80	6.00
Taxes, 1%	1.00	1.30	2.40	3.00
Total cost per annum	$573.56	$1,037.20	$1,532.60	$2,572.00
Cost of 1 hp. per annum, 10-hour basis	$286.78	$172.86	$153.20	$128.60
Cost of 1 hp. per hour	$0.0928	$0.0558	$0.0497	$0.0417

III.—Cost of Gas Power (1912)

Illuminating gas used. 760 B. T. U. No estimate is made on the cost of gas power using producer gas, as it would not pay to put in a gas producer for so small a unit.

$1.50 per 1,000 cu. ft. of gas less 20%, if paid in 10 days = $1.20 net, gas 760 B. T. U.

Size of plant in hp.	2	6	10	20
Engine cost if in place	$200.00	$375.00	$550.00	$1,050.00
Gas per hp. in feet	30	25	22	20
Value of gas consumed, 3,080 hours	$221.76	$554.40	$843.12	$1,478.00
Attendance, $1 per day	308.00	308.00	308.00	308.00
Interest, 5%	10.00	18.75	27.50	52.50
Depreciation, 5%	10.00	18.75	27.50	52.50
Repairs, 10%	20.00	37.50	55.00	105.00
Supplies, 20%	40.00	75.00	110.00	210.00
Insurance, 2%	4.00	7.50	11.00	21.00
Taxes, 1%	2.00	3.75	5.50	10.50
Power cost	$615.76	$1,023.65	$1,387.62	$2,237.50
Annual charge for space	9.00	13.50	18.00	27.00
Total cost per annum	$624.76	$1,037.15	$1,405.62	$2,264.50
Cost of 1 hp. per annum, 10-hour basis	$312.28	$172.86	$140.56	$113.22
Cost of 1 hp. per hour	$0.1014	$0.0561	$0.0456	$0.0367

IV.—Cost of Steam Power (1912)

Size of plant in hp.	6	10	20
Cost of plant per hp.	$250.00	$220.00	$200.00
Fixed charge, 14%	35.00	30.80	28.00
Coal per hp. hour, in lb.	20	15	12
Cost of coal at $5 per ton	$154.00	$103.00	$ 82.50
Attendance, 3,080 hours	75.00	50.00	30.00
Oil waste and supplies	15.00	10.00	6.00
Cost 1 hp. per annum, 10-hr. basis	$279.00	$194.80	$146.50
Cost of 1 hp. per hour	$0.0906	$0.0832	$0.0475

Mr. Webber has elsewhere observed the fact that a gas engine of single cylinder type, which will operate on ⅛ gal. of fuel per hp. at full load will perhaps require over a gallon of hp. at a 10% load; and a small steam engine, which will run on 5 pounds of coal per hp. per hour at full load may need 15 pounds at ¼ load.

Mr. W. O. Webber has also given, in the *Engineering Magazine*, some interesting detailed figures on the cost of steam plant installation, which are given in the following table:

Cost of Installation of a 10-Horsepower Steam Plant (1912)

Land for engine and boiler room, 300 sq. ft. @ $1.	$300.00	
Boiler and engine room building, 300 sq. ft. @ $1.50	450.00	
Chimney, 10″ x 40′	400.00	
		$1,150.00

10-horsepower boiler	241.00	
Boiler foundation and setting, 3,900 C. B. 500 F. B.	160.00	
Blow-off tank	31.00	
Damper and regulator	75.00	
Injector tank	10.00	
Water meter	40.00	
Piping for same	20.00	
Pump and vacuum	122.00	
Feed water heater	40.00	
Pipe covering	50.00	
		789.00
Engine, 7 by 10	$184.00	
Foundation for same	60.00	
Steam separator	35.00	
Oil separator	25.00	
Piping	95.00	
Freight and cartage	30.00	
		429.00
		$2,378.00

Cost of Installation of a 60-Horsepower Steam Plant (1912)

Land for engine and boiler room		$2,500.00
Buildings for engine and boiler room		2,500.00
Chimney		1,200.00
80-horsepower boiler	$ 790.00	
Ash pan for boiler (below high tide level)	120.00	
Boiler and engine settings	1,282.00	
Blow-off tank	31.00	
Damper regulator	75.00	
Injector tank	10.00	
Water meter	60.00	
Piping for same	22.13	
Pump and receiver	146.50	
Feed water heater	70.40	
Pipe covering	70.75	
		2,677.78
Engine, 12 by 30	$1,065.00	
Pan for engine fly-wheel	72.00	
Steam separator	60.00	
Oil separator	41.80	
Piping, freight and cartage	1,026.41	
		2,265.27
Shafting in place	$ 550.00	
Belting in place	285.00	
		835.00
		$11,977.99

$11,977.99 ÷ 60 = $199.63 per hp.

Mr. Wm. E. Snow has contributed to the engineering press some extremely useful tables of the various costs of steam plant for different sizes of installation.

From his figures of 1908 I have compiled the following three diagrams, Figs. 257, 258, 259, which show graphically the effect of size of plant upon the various elements of cost.

First Cost and Cost of Operating Power Plants for Driving North River Tunnels of Pennsylvania Railroad, New York City.

(Extract from a paper entitled "The New York Extension of the Pennsylvania Railroad North River Tunnels," by B. H. M.

Hewett and W. L. Brown, Proceedings American Society of Civil Engineers, 1910, Vol. XXXVI, p. 690.) Two power plants were constructed, one on each side of the river. The plants contained in the two power houses were almost identical, there being only slight differences in the details of arrangement due to local conditions. A list of the main items of the plant at one power house is shown in Table I. A summary of the first cost of one plant is given in Table II.

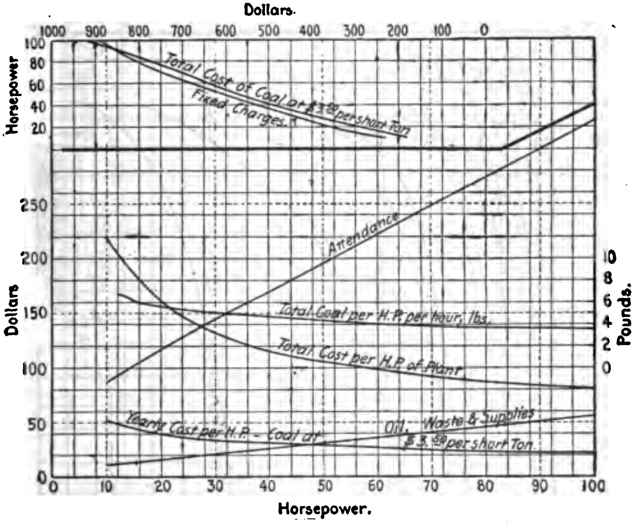


Fig. 257. Approximate Yearly Costs of Steam Power, 150 Days, 10 Hours per Day, Simple Condensing. Plotted from Data Compiled by Wm. E. Snow, 1908.

TABLE I — PLANT AT ONE POWER HOUSE (1910)

Description of Item.	Cost.
3 500-hp. water tube Sterling boilers	$ 15,186
2 feed pumps, George F. Blake Manufacturing Co.	740
1 Henry R. Worthington surface condenser	6,539
2 electrically driven circulating pumps on river front	5,961
3 low-pressure compressors, Ingersoll-Sergeant Drill Co.	33,780
1 high-pressure compressor, Ingersoll-Sergeant Drill Co.	6,665
3 hydraulic power pumps, George F. Blake Mfg. Co.	3,075
2 General Electric Co.'s generators coupled to Ball and Wood engines	7,626
Total cost of main items of plant (1910)	$ 79,572

TABLE II — SUMMARY OF COST OF ONE PLANT (1910)

Total cost of main items of plant	$ 79,572
Cost of four shields (including installation, demolition, large additions and renewals, piping, pumps, etc.)	103,560
Cost of piping, connections, drills, derricks, installation of offices and all miscellaneous plants	101,818
Cost of installation, including preparation of site	39,534
Total prime cost of one power house plant (1910)	$324,484

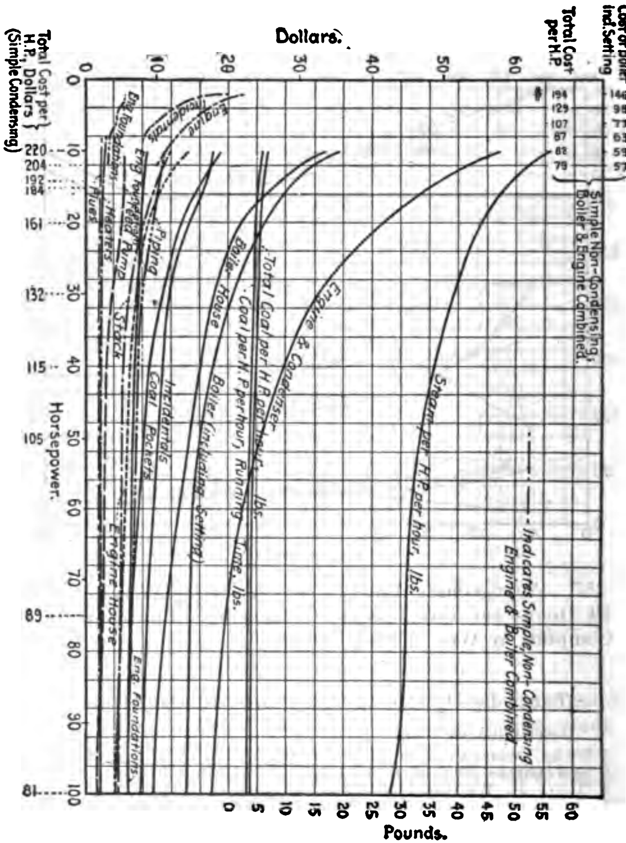


Fig. 258. Approximate Costs per Horsepower of Steam Power Plants Complete, Simple Condensing. Plotted from Data Compiled by Wm. E. Snow, 1908.

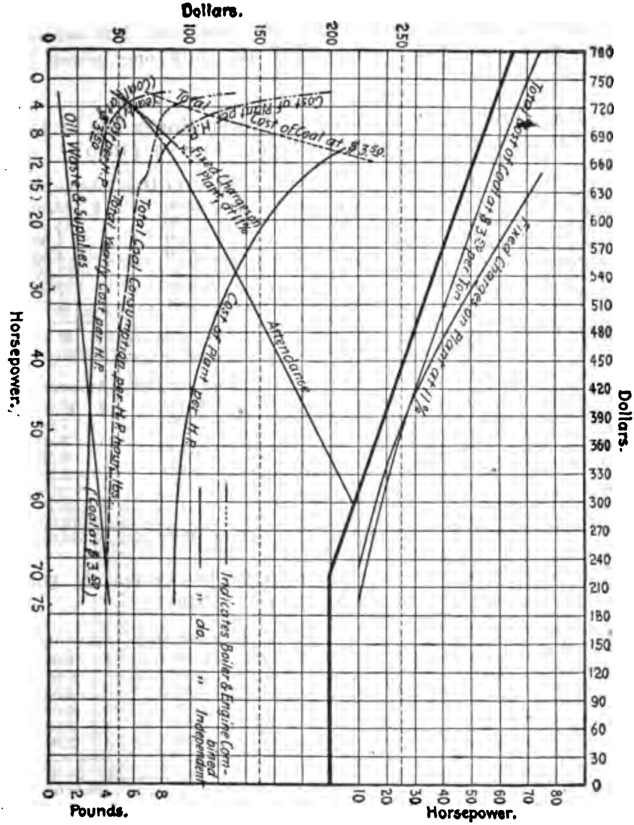


Fig. 259. Approximate Yearly Costs of Steam Power, 150 Days, 10 hrs. per Day, Simple Non-Condensing. Plotted from Data Compiled by Wm. E. Snow, 1908.

In order to give an idea of the general cost of running these plants, Tables III and IV are given as typical of the force employed and the general supplies needed for a 24-hour run of one plant. Table III gives a typical run during the period of driving the shields, and Table IV is typical of the period of concrete construction. In the latter case the tunnels were under normal

air pressure. Before the junction of the shields both plants were running continuously; after the junction, but while the tunnels were still under compressed air, only one power house plant was operated.

TABLE III — COST OF OPERATING ONE POWER HOUSE FOR 24 HOURS DURING EXCAVATION AND METAL LINING (1910)

Labor.	Rate per Day.	Amount.
6 Engineers	$3.00	$ 18.00
6 Firemen	2.50	15.00
2 Oilers	2.00	4.00
2 Laborers	2.00	4.00
4 Pumpmen	2.75	11.00
2 Electricians	3.50	7.00
1 Helper	3.00	3.00
Total per day		$ 62.00
Total for 30 days		$1,860.00

Supplies.	Rate per Day.	Amount.
Coal (14 tons per day)	$3.25	$ 45.50
Water	7.00	7.00
Oil (4 gals. per day)	0.50	2.00
Waste (4 lb. per day)	0.07	0.28
Other supplies	1.00	1.00
Total per day		$ 55.78
Total for 30 days		1,673.00
Total cost of labor and supplies for 30 days (1910)		3,533.00

TABLE IV — COST OF OPERATING THE ONE PLANT FOR 24 HOURS DURING CONCRETE LINING (1910)

Labor.	Rate per Day.	Amount.
2 Engineers	$3.00	$ 6.00
2 Firemen	2.50	5.00
2 Pumpmen	3.00	6.00
1 Foreman electrician	6.00	6.00
1 Electrician	3.00	3.00
1 Laborer	2.00	2.00
Total per day		$ 28.00
Total for 30 days		840.00

Supplies.	Rate per Day.	Amount.
Coal (14 tons per day)	$ 3.15	$ 44.10
Oil (4 gals. per day)	0.50	2.00
Water	13.00	13.00
Other supplies	2.00	2.00
Total per day		$ 61.10
Total for 30 days		1,833.00
Total cost of labor and supplies for 30 days		2,673.00

SECTION 74

PUMPS

I have taken the following classification of pumps from Turneaure and Russell's "Public Water Supplies":

Pumps may be classified in various ways, but for the consideration of their mechanical action they may be best considered under the following heads:

1. Displacement-pumps.
2. Impeller-pumps.
3. Impulse-pumps.
4. Bucket-pumps.

Fig. 260. Submerged Type.

The various subdivisions of the classification are shown in table below:

- Pumps
  - Absolute volume displaced
    - Displacement
      - Reciprocating
        - Action
          - Double
          - Single
        - Class
          - Piston
          - Plunger
            - Inside-packed
            - Outside-packed
            - Center-packed
        - Type
          - Power
            - Single
            - Duplex
            - Triplex
          - Steam
            - Application
              - High-pressure
              - Compound
            - Arrangement
              - Direct-acting
              - Crank & fly-wheel
              - Compensator
          - Hydraulic
            - Direct-acting
            - Crank and fly-wheel
        - Arrangement
          - Horizontal
          - Vertical
        - Use
          - Surface (suction)
          - Submerged or deep well
      - Rotary
      - Air-displacement, Steam-vacuum, Continuous-flow
        - Screw
        - Chain
        - U pump
        - Double-acting
  - Impeller
  - Continuous application through some mechanical agency or medium
    - Centrifugal
      - Impeller
        - Opened
        - Closed
      - Case
        - Side suction
        - Double suction
      - Arrangement
        - Horizontal
        - Vertical
    - Jet
      - Water
      - Steam
      - Air
  - Impulse (as name implies) — Water-ram
  - Bucket (receptacle alternately filled and emptied)
    - Wheel
    - Band

Centrifugal Pumps. The centrifugal pump (Fig. 260) has been so developed and perfected that it is now recognized as a simple, reliable pump of great range.

The principal trouble with a centrifugal pump, especially when the pump is at a substantial height above the water, is in starting it. When the pump sucks it must be reprimed and

started again. Therefore, if the amount of water to be handled is not as great as the minimum capacity there will be many stops and knock-offs to prime. Before starting up a steam pump, especially in cold weather, it should be well warmed up by live steam from the end of a hose in order to thaw out any ice that may have formed in the cylinders and to give the iron parts a chance to expand gradually.

Iron Vertical Centrifugal Pumps, submerged or suction type, furnished complete with short shaft and coupling, one bearing, pulley for connecting shaft and discharge elbow, are used extensively for irrigation purposes, sewage pumping, and for any place where a pump may be placed in a pit. Suitable for elevating water 50 to 60 feet.

IRON VERTICAL CENTRIFUGAL PUMPS

Discharge	Hp. required for Each Ft. Elev.	Diam. & Face of Pulley (In.)	Capacity per Min. (Gals.)	Floor Space Required.	Shipping Wt. (Lb.) Submerged Type	Shipping Wt. (Lb.) Suction Type	Price Complete Submerged Type	Price Complete Suction Type
1½	.058	5 x 6	70	2′ 9″	120	135	$ 40	$ 60
2	.10	7 x 8	120	3′ 4″	198	250	64	100
3	.22	7 x 8	260	3′ 6″	235	340	94	146
4	.30	8 x 10	470	4′ 0″	380	495	110	170
5	.45	10 x 10	735	4′ 7″	605	785	140	210
6	.59	12 x 12	1,050	4′ 7″	740	1,050	170	280
10	1.52	20 x 12	3,000	5′ 5″	1,430	1,925	330	550
12	2.00	24 x 14	4,200	6′ 0″	2,640	3,000	410	700
*12	2.00	20 x 12	4,200	3′ 9″	2,000	2,500	370	650
18	4.50	36 x 18	10,000	7′ 0″	6,000	7,000	940	1580
*18	4.50	30 x 16	10,000	6′ 6″	2,900	3,300	840	1420

* Refers to low-lift pumps for elevations up to 25 feet.

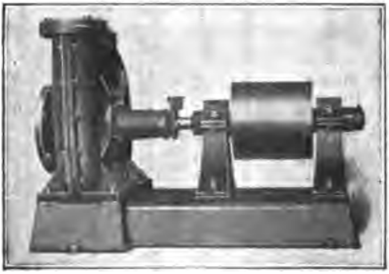


Fig. 261. Horizontal Type.

Iron Horizontal Centrifugal Pumps for belt drive. A pump used extensively for all purposes.

IRON HORIZONTAL CENTRIFUGAL PUMPS

Discharge	Suction	Capacity per Min. (Gals.)	Hp. for Each Ft. of Elevation	Diam. & Face of Pulley (In.)	Floor Space (In.)	Shipping Wt. (Lb.)	Price
1½	2	70	.058	6 x 6	17 x 31	175	$ 45
2	3	120	.10	8 x 8	23 x 37	350	75
3	4	260	.22	8 x 8	25 x 39	415	110
4	5	470	.30	10 x 10	29 x 41	615	130
5	6	735	.45	12 x 12	34 x 54	940	165
6	8	1,050	.59	15 x 12	37 x 56	1,180	200
10	12	3,000	1.52	24 x 22	51 x 69	2,610	395
12	15	4,200	2.00	30 x 14	63 x 71	3,615	500
*12	12	4,200	2.00	20 x 12	51 x 59	2,800	500
18	20	10,000	4.50	40 x 16	93 x 103	9,000	1,300
*18	20	10,000	4.50	30 x 16	66 x 72	5,800	1,150
*24	24	15,000	6.50	48 x 20	90 x 98	10,800	2,150
24	24	15,000	6.50	48 x 36	94 x 137	13,000	3,000

* Low-lift pumps for elevations up to 25 feet.

The above pump, fitted with a direct connected vertical steam engine costs: 4 in. side suction, 4 x 4 in. engine $420; weight, 1,290 lb. 5 in. side suction, 5 x 5 engine, $450; weight, 1,440 lb. 6 in. side suction 6 x 6 in. engine, $475; weight, 1,570 lb.

DIRECT CONNECTED DREDGING PUMPS

No. Pump & Diam. of Suction & Discharge	Total Head	Engine Description	Size of Cylinders		Capacity, Yd. per Hr. (20% Solids)	Largest Diam. of Solids (In.)	Weight (Lb.)	Price
			Stroke	Diam.				
4	15	Single	5	5	30	2	1,600	$ 448
4	20	Single	6	6	30	2	1,800	480
4	25	Double	5	5	30	2	2,000	656
6	15	Single	6	6	60	4	2,500	570
6	20	Single	7	7	60	4	2,700	632
6	25	Double	6	6	60	4	3,000	830
8	15	Single	9	9	125	6	4,750	1,000
8	20	Double	7	7	125	6	5,800	1,130
8	25	Double	8	8	125	6	6,500	1,450
10	15	Single	10	10	200	8	7,500	1,290
10	20	Double	9	9	200	8	9,500	1,650
10	25	Double	10	10	200	8	10,500	2,000
12	15	Single	12	12	300	10	10,000	1,780
12	20	Double	10	10	300	10	12,800	2,140
12	25	Double	12	12	300	10	16,000	2,970

Direct Connected Dredging Pumps, complete with suction and lischarge elbow, flap valve and steam primers, lubricator and ›il cups. Cast iron impellor. The shipping weight and the price nay vary 20% from the averages given in table.

Belt Driven Sand and Dredging Pumps, complete except for pipe ›r hose.

BELT DRIVEN PUMPS

Catalog No.	Diam. of Suction and Discharge	Capacity, Yd. per Hr. (20% Solids)	Hp. Required per 10' Head.	Diameter and Face of Pulley	Shipping Weight (Lb.)	Largest Diam. of Solids (In.)	Price
4	4	30	4	12 x 12	1,200	2	$216
6	6	60	8	18 x 12	1,850	4½	310
8	8	125	15	24 x 12	3,600	6	490
10	10	200	25	30 x 14	4,550	8	620
12	12	300	30	40 x 16	8,000	10	870

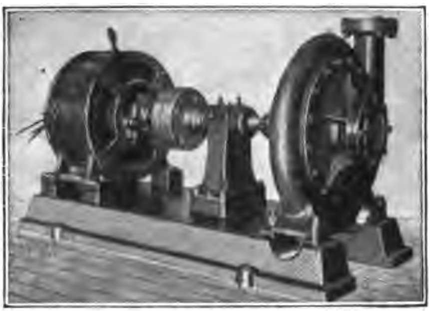


Fig. 262. Standard Side Suction Volute Pump.

Another make of belt driven centrifugal pumps costs as follows:

Discharge dia. in in.	Capacity in gal. per min. Head in ft. 10	20	30	40	50	60	70	Wt. in lb.	Price f. o. b. factory
1	35	54	62	70	75	80	90	100	$ 45
1½	70	100	120	140	155	165	180	150	65
2	104	147	190	220	260	280	300	250	75
2½	130	200	240	260	296	316	330	275	85
3	200	310	380	430	480	510	550	450	115
4	350	590	600	700	770	850	920	550	140
5	600	850	1000	1130	1270	1400	1500	750	180
6	750	1050	1305	1570	1620	1770	1905	850	200
8	1250	1860	2100	2400	2700	2900	3100	1250	275
10	2050	3000	3650	4200	4700	4500	4000	1900	375
12	3200	4200	4960	5400	5800	6040	6200	2750	525

The above machines are of the single suction open impeller type and are used for low lifts and gritty water.

Double Suction Centrifugal Pumps used for general service are made in a wide diversity of sizes and capacities. In this type of centrifugal pump each different condition requires a special design of pump and equipment and it is impossible to give sizes and other data within the available space.

Multi-Stage Centrifugal Pumps used for heavy duty and high lifts are also specially designed for each particular job.

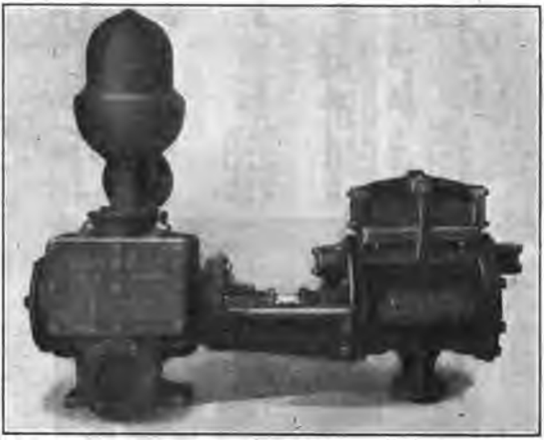


Fig. 263. Direct Acting Piston Pump.

Direct Acting Piston Pumps designed for general service, made with iron water cylinder, bronze lined, and bronze piston rod, cost as follows:

Suction pipe, in.	Discharge pipe, in.	Dia. water cyl. inches	Stroke inches	Gallons per min.	Weight in lb.	Price f. o. b. factory
1¼	1	2	6	12	210	$ 120
1½	1¼	2½	6	19	250	125
2½	2	4	7	49	458	180
3	2½	4	12	81	680	240
4	3	5	13	130	1145	325
5	4	7	13	206	1830	475
6	5	9	18	248	3250	825
8	6	10	18	408	3700	1100
10	8	12	20	510	5570	1500

Vertical Plunger Sinking Pump used in sinking a mine shaft, etc., for gritty water, requiring a minimum amount of attention, costs as follows:

Suction pipe, in.	Discharge pipe, in.	Dia. water cyl. inches	Stroke inches	Gallons per min.	Weight in lb.	Price f. o. b. factory
3	2½	4	12	83	1526	$ 340
4	3	5	13	130	2308	460
5	4	7	13	296	3424	600
6	5	9	16	247	6070	1000
8	6	10½	16	427	8800	1500

The capacities in gallons per minute of the above two types must be reduced 20% if the lift is high.

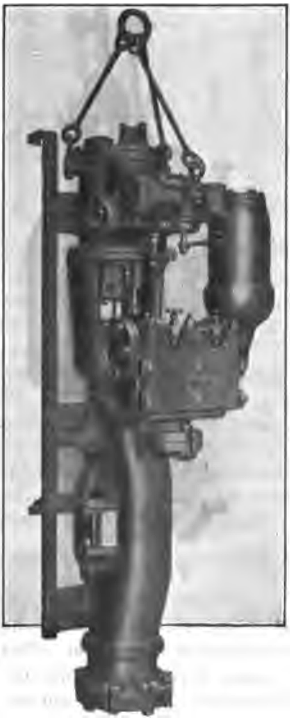


Fig. 264. Vertical Plunger Sinking Pump.

Contractor's Differential Plunger Pump, adapted to work where the lift is light and the water contains considerable sediment is rated at a displacement of from 50 to 63 gal. per min., weighs 530 lb. and costs $260. The diameter of the suction pipe is 3 in.,

discharge, 2½ in. Diameter of the steam pipe is ¾ in., exhaust pipe 1 in.

Pulsometer. A very well known steam operated vacuum pump is the one illustrated in Fig. 265. It consists of two bottle shaped cylinders with the necessary valve inlet and outlet pipes. The operation of this pump is sustained by alternate pressure and vacuum. Steam, cushioned by a layer of air automatically admitted, is brought to bear directly upon the liquid in the pump

Fig. 265.

chambers and forces it out through the discharge pipe; the subsequent rapid condensation of the steam, effected by the peculiar construction of the pump, forms a vacuum in the working chambers, into which atmospheric pressure forces a fresh supply of liquid through the suction pipe. This action is maintained quite automatically, and is governed by a self-acting valve ball in the neck of the pump, which obeys the combined influences of steam pressure on one side and vacuum on the other. The valve ball oscillates from its seat in the entrance to one chamber to its seat in the entrance to the other chamber, thereby distributing the steam.

This pump will do all classes of rough service raising water up to 75 feet elevation. It has no piston, no packing, no oil, and seldom breaks down, but is very uneconomical of steam.

Pulsometer Pumps

	Size of Pipe (In.)			Capacity in Gals. per Min. at Different Elevations and Boiler Hp.				Price, f. o. b. New York		
Catalog No.	Steam	Suction	Discharge	25 Ft.	50 Ft.	75 Ft.	Hp.	Flat Valve (Standard)	Ball Valve (Special)	Weight (Lb.)
2	¼	1½	1½	20	17	13	4	$ 148	$165	95
3	⅜	2	2	60	50	38	5	210	225	140
4	½	2½	2½	100	80	65	6	300	320	295
5	½	3	3	180	160	115	9	315	333	430
6	¾	3½	3½	300	265	200	12	385	437	570
7	¾	4	4	425	375	275	15	480	520	745
8	1	5	5	700	625	450	25	690	755	1,375
9	1½	11	6	1,000	900	650	35	900	970	2,100
10	2	8	8	2,000	1,800	1,400	70	1,800	....	3,800

Each pump is furnished complete with either basket or mushroom strained steam and release valve connection, and pump hook for suspending when necessary, but no piping.

These pumps will work, admitting 30% of air or 25% of grit, and a continuous run of four months has been recorded. They are especially valuable in quicksand and wherever the quantity of water is variable. The cost of repairs is nominal.

These pumps are made in two types; the standard consists of two vertical cylinders, each with a discharge and suction valve, topped by one simple, three-cylinder horizontal engine, with the necessary air cocks, lubricator and condenser piping, but no steam, suction or discharge pipe is supplied.

Steam Operated Vacuum Pumps

Standard

Capacity in gal. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
140	525	$ 195
200	725	235
260	900	300
450	1,050	385
735	1,700	550
1,150	2,075	770
2,000	5,500	1,270
3,000	6,000	1,650

The capacities in the above table are calculated on a head or lift of 20 ft. They diminish at the rate of about 4% for every 10 ft. additional up to 150 ft., the highest head recommended.

Junior

Capacity in gal. per min.	Approximate shipping weight in lb.	Price f. o. b. factory
75	275	$110
100	350	138

The Junior consists of a single cylinder, a steam piston valve, suction valve, discharge valve, condenser pipe, check valve and stop cock, and is furnished with the patented foot valve and quick cleaning strainer.

Capacities stated in table in gallons per minute and per hour are calculated on a head or lift of 20 feet. These capacities diminish at the rate of about 6% for each 10 feet of additional head up to 100 feet, the highest lift.

Hand Diaphragm Pumps, used upon cofferdams, pier foundations, trench work and all work of similar kind, are made in several sizes. Two sizes of one make are as follows: Capacity per

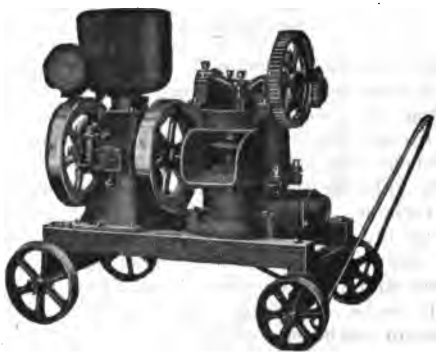


Fig. 266. Diaphragm Pump.

stroke 1 gal., 3-in. suction, weight 185 lb., price $36; capacity per stroke 2 gal., 4-in. suction, weight 290 lb., price $60. Prices include hand brake or handle, but no hose.

Hand Trench Pump of the diaphragm type rated at from 600 to 800 gal per hr. when operated by one man, and rated to lift water 20 ft. and to force it 50 ft. higher, is mounted on a board and costs $25. Price of this pump including 10 ft. of suction hose and 25 ft. of linen discharge hose, all coupled up, is $50.

Pumping Units. There are a great many makes of gasoline driven pumping units of several types on the market. The following are the prices of a few of the makes.

Diaphragm Pumps for Long and Continuous Operation

3-in. pump on skids without engine, capacity 3000 gal. per hr.	$100
3-in. pump on skids, 2½ hp. engine, shipping weight 580 lb...	210
3-in. pump on trucks, 2½ hp. engine, shipping weight 650 lb.	230
4-in. pump on skids without engine, capacity 4500 gal. per hr.	130
4-in. pump on skids, 2½ hp. engine, shipping weight 650 lb...	240
4-in. pump on trucks, 2½ hp. engine, shipping weight 850 lb.	260

Double Diaphragm Pumps Mounted on Trucks

Capacity in gal. per hr.	Hp. of engine	Shipping weight in lb.	Price f. o. b. Michigan
6,000	2½	1,150	$290
6,000	3½	1,300	315
10,000	3½	1,510	360
10,000	4½	1,625	395

Triplex Pumping Outfits Mounted on Skids

Capacity in gal. per hr.	Hp. of engine	Shipping weight in lb.	Price f. o. b. Michigan
900	2½	1,000	$360
1,300	3½	1,300	450
1,950	4½	1,500	560
1,950	6	2,000	625
3,000	6	2,100	800
3,000	8	2,225	900
4,800	10	5,000	1,325

In the above add $25 for hand trucks. Pump operates at a pressure of 150 lb., the total head in ft. is 350.

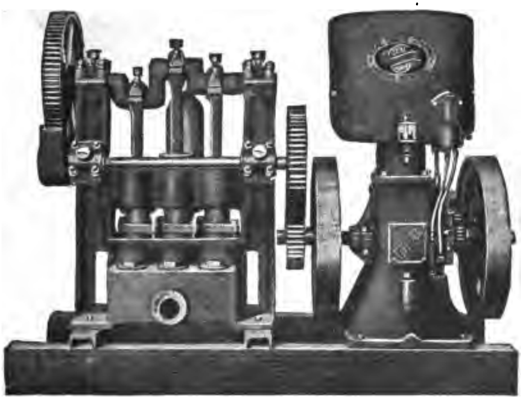


Fig. 267. Triplex Pump.

High Pressure Force Pumps on Skids

Capacity in gal. per hr.	Hp. of engine	Shipping weight in lb.	Price f. o. b. Michigan
900	3½	735	$300
900	4½	790	335
1,300	4½	1,000	375
1,500	6	1,225	440
2,200	6	1,525	490
2,400	8	1,650	550

In the above, add $20 for hand trucks. The total head for the above is 400 and 515 ft. the pressure is 175 and 225 lb. per sq. in. Magnetos for all the foregoing types cost $50 extra.

Fig. 268. Force Pump.

Pump Accessories

3-inch rubber suction hose, per ft.	$ 1.55
4-inch rubber suction hose, per ft.	2.50
Brass hose couplings for 3-inch, per set	5.50
Brass hose couplings for 4-inch, per set	10.65
Galvanized strainer and foot valve for 3-inch	3.85
Galvanized strainer and foot valve for 4-inch	6.25
Hose bands for 3-inch, each	.40
Hose bands for 4-inch, each	.65
Rubber diaphragm for 3-inch pump	3.00
Rubber diaphragm for 4-inch pump	3.50

Another make of pumps costs as follows:

Outfit No. 1, engine 1½ hp., 3 in. suction diaphragm pump, capacity 3,000 to 5,000 gal. per hr., depending on conditions, weight 650 lb., price $230.

Outfit No. 2, engine 2 hp., 4 in. suction diaphragm pump, capacity 7,200 to 8,400 gal. per hr., depending on conditions, weight 925 lb., price $270.

Outfit No. 3, engine 3½ hp., two 4 inch diaphragm pumps, capacity 12,000 to 17,000 gal. per hr., depending on conditions, weight 1,530 lb., price $410.

Outfit No. 4, engine 2 hp., connected to 3 inch Cesspool diaphragm pump, capacity 2,000 to 4,600 gal. per hr, weight 950 lb., price $310.

Outfit No. 5, engine 3½ hp., connected to a 3 inch suction centrifugal pump, capacity 150 to 250 gal. per min., weight 1,250 lb., price $430.

Outfit No. 6, engine 2 hp., connected suction and force pump of piston type, capacity 1,000 to 18,000 gal. per hour, weight 725 lb., price $250.

Outfit No. 7, engine 3½ hp., connected to piston pump cylinder, capacity 2,000 gal. per hr., weight 950 lb., price $335.

Outfit No. 8, engine 3½ hp, connected to 3 in. centrifugal pump and diaphragm pump, capacity of centrifugal pump 12,000 gal. per hour, diaphragm pump 6,000 to 84,000 gal. per hr., weight 1,600 lb., price $550.

Extras for above:

High hand truck	$ 30
One horse truck with shafts	96
Two horse truck with pole	108
Neck yoke single and double trees	12
If engines are wanted without trucks deduct	20

Uses for above. Outfits 1 and 2 for trenches and excavations, etc., where water can flow away by gravity.

Outfit 2 has large capacity and can be used to remove water from two places at the same time.

Outfit 4 used for removal of sewage water from cesspools and drains.

Outfit 5 used for low lifts and gritty water.

Outfit 6 used for pumping from drains and culverts and small excavations; for filling tanks, watering carts and boilers; for supplying concrete mixers; will elevate water to maximum height of 235 ft.

Outfit 7 used for road work, will deliver water for distance of two miles, or elevate water to height of from 100 to 300 ft.

Outfit 8 combining advantages of outfits 2 and 5.

Hose and Fittings

Suction hose, 2 inch, per ft.	$ 1.50
Suction hose, 3 inch, per ft.	1.80
Suction hose, 4 inch, per ft.	3.00
Discharge hose, 1½ inch, per ft.	.36

Discharge hose, 2 inch, per ft.	.48
Discharge hose, 3 inch, per ft.	.72
Brass couplings, 1½ inch, per set	1.80
Brass couplings, 2 inch, per set	3.60
Brass couplings, 3 inch, per set	5.40
Brass couplings, 4 inch, per set	10.20
Strainers, 2 inch iron	.72
Strainers, 3 inch iron and foot valve	3.00
Strainers, 4 inch iron and foot valve	3.40
Diaphragms, 2 inch	2.00
Diaphragms, 3 inch	2.40
Diaphragms, 4 inch	3.20

RAILS AND TRACKS

Steel Rails. Following are the quotations Jan., 1920, f. o. b. Pittsburgh.

Standard Bessemer rails	$45.00 per ton carload lots
Standard open hearth rails	47.00 per ton carload lots
Light rails, 8 to 10 lb.	2.58 per 100 lb.
Light rails, 12 to 14 lb.	2.54 per 100 lb.
Light rails, 25 to 45 lb.	2.45 per 100 lb.

Track Supplies. Jan., 1920, f. o. b. Pittsburgh.

Standard spikes, 9/16 in. and larger	$3.35
Track bolts	4.35
Standard section angle bars	3.00

Railway Ties. Prices in fair sized lots Jan., 1920:

Size	Wood	Place	Price per tie
6 by 8 by 8	Fir-green	San Francisco	$1 14
6 by 8 by 8	Fir-creosoted	San Francisco	2.28
6 by 8 by 8	White oak	Missouri Mills	.85
7 by 9 by 8	White oak	Missouri Mills	1.05
6 by 8 by 8	Red oak	Missouri Mills	.70
7 by 9 by 8	Red oak	Missouri Mills	80

Add $0.36 each for treatment.

The A. S. C. E. rail sections are most generally used and their dimensions are as follows:

Wt. rail (lb. per yd.)	Base (in.)	Tread (in.)	Wt.. rail (lb. per yd.)	Base (in.)	Tread (in.)
8	1 9/16	13/16	55	4 1/16	2 1/4
12	2	1	60	4 1/4	2 3/8
14	2 1/16	1 1/16	65	4 7/16	2 13/32
16	2 3/8	1 11/64	70	4 5/8	2 7/16
20	2 5/8	1 11/32	75	4 13/16	2 15/32
25	2 3/4	1 1/2	80	5	2 1/2
30	3 1/8	1 11/16	85	5 3/16	2 9/16
35	3 5/16	1 3/4	90	5 3/8	2 5/8
40	3 1/2	1 7/8	95	5 9/16	2 11/16
45	3 11/16	2	100	5 3/4	2 3/4
50	3 7/8	2 1/8			

One flat car will hold about 60 rails of 80 lb. section.

The ordinary R. R. rails are classified about as follows:

WEIGHTS PER MILE OF RAIL AND FASTENINGS, SINGLE TRACK

Weight of rail, lb. per yard	Section No.	Number of pairs of splice bars	Number of bolts	Number of spikes	Weight of splice bars, gr. tons	Weight of bolts, gr. tons	Weight of spikes, gr. tons	Total weight of fastenings, gr. tons	Weight of rails, gr. tons	Total weight of rails and fastenings, gr. tons	Specification of length of rails, feet
8	..	364	1456	10640	0.33	0.07	0.43	0.83	12.57	13.40	90% — 30 feet long and 10% short, down to 20 feet
9	..	364	1456	10640	0.375	0.07	0.43	0.875	14.14	15.015	
10	..	364	1456	10640	0.42	0.07	0.43	0.92	15.71	16.63	
12	9	364	1456	10640	0.56	0.15	0.77	1.48	18.86	20.34	
14	8	364	1456	10640	0.56	0.15	0.77	1.48	22.00	23.48	
16	7	364	1456	10640	0.71	0.15	0.81	1.67	25.14	26.81	
20	6	364	1456	10640	0.79	0.16	1.53	2.48	31.43	33.91	
25	5	364	1456	10640	0.93	0.16	1.59	2.68	39.29	41.97	
30	4	364	1456	10640	1.70	0.30	1.59	3.59	47.14	50.73	
35	3	364	1456	10640	1.97	0.30	1.78	4.05	55.00	59.05	
40	2	364	1456	10640	2.62	0.47	1.94	5.03	62.86	67.89	
45	1	364	1456	10640	3.04	0.47	2.79	6.31	70.71	77.02	
50	A. S. C. E.	326	1304	10640	3.71	0.44	2.80	6.95	78.57	85.52	90% — 30 feet long, 10% short, varying by even feet down to 24 ft.
55	A. S. C. E.	326	1304	10640	4.20	0.46	2.80	7.46	86.43	93.89	
60	A. S. C. E.	326	1304	10640	4.71	0.46	2.80	7.97	94.29	102.26	
65	A. S. C. E.	326	1304	10640	5.17	0.48	2.80	8.45	102.12	110 57	
70	A. S. C. E.	326	1956	10640	7.96	0.71	2.80	11.47	110.00	121.47	
75	A. S. C. E.	326	1956	10640	8.52	0.74	2.80	12.06	117.86	129.92	
80	A. S. C. E.	326	1956	10640	9.07	0.75	2.80	12.62	125.71	138.33	

I. Fit for main track on a standard railroad.
II. Sides worn from curves but perfectly smooth.
III. In good condition but with battered ends which can be cut off and the bolt holes rebored.
IV. Fit only for sidings.

Fishplates and Bolts Required for One Mile Single Track

Length of rail	Complete joints	Length of rail	Complete joints
All 21 feet	503	All 30 feet	352
All 24 feet	440	90%, 30 feet; 10%, shorter	
All 26 feet	406		
All 28 feet	377		358

Each joint consists of two plates and four bolts and nuts. Therefore the number of plates required is twice as many as the number of complete joints, and the number of bolts required is four times as many. If six bolts are required for a joint, then the number of bolts will be six times the number of complete joints.

Railroad Spikes

Size measured under head	Average number per keg of 200 pounds	Ties 2 feet between centers, 4 spikes per tie needed per mile	Rail used, weight per yard
6 x 9/16	320	6600 pounds — 32 kegs	
5½ x 9/16	375	5870 pounds — 30 kegs	45 to 100
5 x 9/16	400	5170 pounds — 26 kegs	40 to 56
5 x ½	450	4660 pounds — 23½ kegs	35 to 40
4½ x ½	530	3960 pounds — 20 kegs	
4½ x 7/16	680	3110 pounds — 15½ kegs	25 to 35
4 x ½	600	3520 pounds — 17⅔ kegs	
4 x 7/16	720	2910 pounds — 14¾ kegs	
4 x ⅜	1000	2090 pounds — 10½ kegs	
3½ x ½	800	2200 pounds — 11 kegs	
3½ x 7/16	900	2350 pounds — 12 kegs	16 to 25
3½ x ⅜	1190	1780 pounds — 9 kegs	
3 x ⅜	1240	1710 pounds — 8½ kegs	
2½ x ⅜	1342	1575 pounds — 7⅞ kegs	12 to 16

Portable Tracks are used mainly for industrial purposes, especially in plantations, mines, handling lumber, quarries, wharves, power and industrial plants, but many times in general contractors' work the use of such track is economical because of its light weight, compactness, and portability. Portable track is usually shipped "knocked down" to save freight charges.

Depreciation. Rails in general lose value from the following causes:

1. Through loss of weight due to corrosion.
2. From becoming bent and unfit for smooth operation.
3. From the weakening effect of attrition or wear.

The first of these causes depends partly upon the climatic conditions and partly upon the nature of the traffic that goes over the rails. Refrigerator cars containing a large amount of brine are very deadly to steel rails because the brine leaking slowly upon the rail tends to keep it more or less saturated with a salt solution which rapidly combines with the iron to form hydrated iron oxide or rust.

The second cause outlined above obtains principally on contractors' light rail, where the rail is too light for the track and where the ties are spaced too far apart. If contractors would appreciate the fact that a rail which has been thoroughly kinked is fit only for scrap and that it need not be kinked at all if the ties are properly spaced, their depreciation on ordinary equipment of this kind would be much less than it usually averages, and there would be the collateral advantage of fewer derailments. Today the habit is growing among contractors to use a rail of heavier section than formerly, and also to space the ties nearer together. These ties should never be more than three ft. apart and seldom more than 30 in. A good weight of rail for narrow gauge track is 40 lb.

Mr. Thos. Andrews has published the results of some examinations of the loss of weight per annum of 11 rails of known age and condition under mail train traffic in England. The first ten of these were in the open and the eleventh, with a life of 7 years, was in a tunnel. The average wear and life of each are given in the following table:

Time life	Average loss of wt. per annum, lb. per yd.
22 years	.260
24 years	0.310
23 years	0.130
23 years	0.130
21 years	0.480
25 years	0.420
17 years	0.320
18 years	0.280
18 years	0.280
19 years	0.630
21 years, average (10)	0.324
7 years	2.800

Contractors' light track of 30-lb. rail with 36-in. gauge was laid on a grading job in 1909. Teams and drivers cost 55 ct.; labor, 15 ct., and foreman, 35 ct. per hour. The rail and ties, which latter were of 6 x 6-in. spruce, 5 ft. long, were gathered from various places on the work and hauled by horses an average distance of 1,500 ft. to the site of the track; 1,000 ft. of track, including 2 complete switches, with ties 4 ft. apart, were laid, at a total labor cost of $56.65, or $0.057 per ft.

1,500 lin. ft. of track, including two switches, similar to above, were laid on another job in five days at the following cost:

1 foreman	at $3.50		$ 17.50
8 men	at 1.50		60.00
1 man	at 2.00		10.00
1 man	at 1.75		8.75
1 team	at 5.00		25.00
Total, 1909			$121.25 = $0.081/ft.

The labor cost of unloading and setting up industrial track in buildings under construction was in 1910 about 3 ct. per lin. ft. of track. It costs about the same to move such track from floor to floor and set up again.

Portable Railways for Hauling Materials for Road Construction. The following is from *Engineering and Contracting* Mar. 4, 1914.

These railways consist of track rails and ties made up into units capable of being carried by two men, and of similar turntable, switch and other special units, all of which are laid down on the ground and connected up to form a continuous line. Transportation over these railways is accomplished by special small cars hauled either by horses or by "dinky" locomotives. For roadwork the portable track is laid along the side of the grade or along the shoulders, and extends from the railway siding, gravel pit, stone quarry or other source of supply to the places where work is being done.

The equipment used consisted of about four miles of narrow-gauge portable track, 40 36 x 24-in. dump cars and two 5-ton dinky locomotives. The cars were hauled in trains of 12 cars each, the arrangement being so made that there was always one train of loaded cars on the way to the site of the work, one train of empties returning for material and one train of cars being loaded. The average amount transported was 80 cu. yd. per day.

While hauling stone three miles from a crusher at the quarry to the road the cost of operating the trains was as follows:

Item	Amount	Per cu. yd.
Materials:		
Fuel and oil for locomotives and cars	$ 8.00	$0.100
Labor:		
2 engineers at $2.75	5.50	0.069
2 brakemen at $1.75	3.50	0.044
1 track foreman at $3	3.00	0.037
1 track laborer at $1.75	1.75	0.022
Totals	$21.75	$0.272

As the material was hauled three miles the unit cost was 9 ct. per cubic yard per mile. The average cost of grading the shoulder

or berm of the road ready for track laying and laying track was between 2 and 3 ct. per foot of track.

Particulars Required for Inquiries and Orders. In order to facilitate the making up of offers and estimates and to save time and unnecessary correspondence, buyers should always answer the following questions as completely as possible:

For Rails. State weight per yard, name of mill rolling the rail and number of section (both of which can be found on web of rail), or send sketch of section or a short sample piece. Also state drilling of same; distance from end of rail to center of first hole and distance from center of first hole to center of second hole, and diameter of holes.

For Switches. Besides the foregoing, state gauge of track, length of switch points, number or angle of frog, style of frog, kind of groundthrow or switchstand, radius desired, whether right, left, two-way or three-way, and whether for wooden ties or mounted on steel ties.

For Crossings. Besides rail section, drilling and gauge, as above, for *all tracks* that are to be connected by the crossing, state angle of crossing, curvature, if any, and style of crossing.

For Turntables. Besides rail section, drilling and gauge, as above, state weight of car, including load to be turned, its wheelbase (wheelbase is the distance from center to center of axle on one side of the car), diameter of wheels, and whether turntable is to be used inside or outside of buildings, and portable or permanent.

For Wheels and Axles. State gauge of track, diameter of wheels, diameter of axles, outside or inside journal and dimensions, load per axle, width of tread, height of flange.

SECTION 76

RAKES

Two-Man Rakes. Two-man rakes, used in leveling broken stone, sell at the following net prices, for quantities, at Chicago:

	Per doz.
10-tooth	$40.00
12 tooth	44.50
14-tooth	49.00

Asphalt or Tar Rakes. Asphalt or tar rakes made of solid steel, with drop shank, strap ferrules, 5-ft. selected white ash handles and 18-in. square iron shanks, sell at a net price, for quantities, at Chicago, of $24.00 per doz.

SECTION 77

REFRIGERATING PLANT

On large jobs where a camp of considerable size is maintained a refrigerating plant would often be very satisfactory. A 3-hp. motor and air compressor with a direct expansion system and brine tank auxiliary for storage will take care of a box 9 x 6 x 11 ft., containing 1½ tons of perishable foods. The first cost of such an equipment would be about $2,000 and the operating cost of electricity about $25.00 per month.

SECTION 78

RIVETING GUNS

The following are the prices of a make of riveting guns:

Rivets up to	Cu. ft. free air per min. 80 lb.	Weight in lb.	Price f. o. b. factory
⅝ in.	19.5	14	$60
¾ in.	22.0	17	65
⅞ in.	30.0	20	70
1¼ in.	30.5	23	80

On Pierson & Son's work on the East River tunnels for the Pennsylvania Railroad 200,000 rivets were required in each of 2 caissons. The record day's work on the caisson was 1,496 rivets by a gang with a Boyer riveter working from a regularly suspended scaffold. One extra man worked in the gang. 1,200 rivets were the ordinary day's work. All rivets had to be tightly driven so as to render work absolutely water tight.

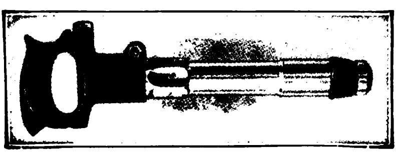


Fig. 269. Riveting Gun.

Steel Rivets. The following were the prices f. o. b. Pittsburgh, January, 1920, per 100 lb.

Structural, ¾ in. and larger		$4.20
Cone head boiler, ¾ in. and larger		4.30
	⅝ and 11/16	4.45
	½ and 9/16	4.70

Lengths shorter than 1-in. take an extra 50 cents.
Lengths between 1-in. and 2-in. take an extra 25 cents.

SECTION 79

ROAD MAKING EQUIPMENT

(See Grading Machines)

Road Construction Plant of the Board of Road Commissioners of Wayne County, Michigan. (From *Engineering-Contracting*, Nov. 9, 1910.) Some years ago Wayne County, Michigan, adopted a plan for the construction of good roads throughout the county. In accordance with this plan a board of county road commissioners, reporting to the county supervisors, was appointed to handle and disburse all money appropriated for county road purposes. A definite systematic plan of road construction covering a period of years was adopted, and work under this plan has now been under way for four years. The work of the commissioners is extensive, covering, as it does, the main highways leading into the city of Detroit and the main highways radiating from the smaller communities in the county. One feature of especial interest in the work of the commissioners is the comparatively large mileage of concrete paved roads that have been constructed. Of this type of road about 15 miles have been completed or are under way at the present time. Most of the road work has been done by day labor, at times as many at 250 men being in the employ of the commission.

In its road work the board has eliminated all hand and horse labor wherever the same or better results could be achieved by machinery. Stone, cement and sand are hauled in trains of from two to six cars holding seven ton loads by road engines. Water is piped and pumped by gasoline engines wherever possible. Plowing and grading are done behind an engine. Concrete is mixed in a mechanical batch mixer which travels under its own power and from which a long crane projects over the work, on which a clamshell bucket travels with the mixed material. The accompanying figures taken from the fourth annual report of the road commissioners for the year ending Sept. 30, 1910, show the original cost of the plant used by the commissioners in their road work:

Hauling and Grading Machinery and Equipment:

Steam engines	2	$ 4,870.00
Road rollers	4	9,607.00
Seven-ton Stone dump wagons	24	6,780.00
Top boxes for same	24	432.00
Tongues for same	1	16.00
Sprinkling wagons	12	2,229.00
Team dump wagons	4	440.00
Graders	2	425.00
Scarifier	1	424.79
Plows	3	61.75
Tool wagons	4	190.00
Tool boxes	2	8.50
Scrapers, Doan	3	15.00
Scrapers, steel	2	9.50
Scrapers, hand	1	1.00
Scrapers, wheeled	4	100.00
		$25,609.54

Concrete Equipment:

Concrete mixers	2	$ 3,475.00
Platform for same	1	23.15
Concrete carts	6	114.00
Wheelbarrows	37	130.27
Road forms	7	45.90
Road irons, 25 feet long	3	17.50
Trowels	2	1.50
Galvanized cylinder	1	2.50
Floats, steel	1	.95
Wire screens	1	1.50
Name plates	2	27.50
2-in. black lead pipe, feet, 5,367	..	302.17
Canvases for protecting concrete	24	433.93
Tarpaulins, 20 x 30	2	78.00
Tarpaulins, 12 x 15	2	23.40
Water tanks, stationary	2	15.00
Hydrant reducer	1	4.75
Special goose neck reducer	1	1.20
Hose	..	15.00
Tampers, various sizes	9	6.75
Iron pins	48	12.00
T-squares (grading bars)	9	9.00
		$ 4,740.97

Maintenance Equipment:

Street sweeper (and extra broom)	1	$ 238.00
Road drag	1	15.63
Scythe and snath	3	5.25
Tar kettles, 100 gallons	2	220.00
Wire and splint brooms	14	8.40
Sprinkling cans	14	14.00
Barrel spouts	15	.90
		$ 502.18

Blacksmithing Outfit and Tools:

Post drill	1	$ 10.50
Ratchet drill	1	6.75
Breast drill	1	3.75
Drill bits	set	4.15
Anvil	1	16.80
Forge	1	10.80

Tongs, pairs	2	4.60
Reamer	1	.50
Hacksaw	1	1.00
		$ 58.85

Shovels and Handled Tools:

Shovels, L. H.	87	$ 63.53
Shovels, D. H.	67	48.40
Shovels, scoop	7	5.25
Spades, garden	7	4.88
Spades, tiling	20	18.90
Stone forks	17	30.69
Picks	47	30.75
Grub hoes	2	1.00
Mattocks	14	11.20
Stone rakes	5	3.75
Post hole digger	1	1.50
Hoes	3	2.75
Crowbars	4	2.40
		$ 225.00

Concrete Tile Making Equipment:

Molds, 8-in.	5	$ 87.50
Molds, 12-in.	7	153.50
Top rings, 8-in.	5	4.00
Top rings, 12-in.	3	2.85
Bottom rings, 8-in.	36	18.00
Bottom rings, 12-in	72	46.90
Irons for bending reinforcement	1	2.00
Pallets	200	27.12
		$ 341.87

Camp Equipment:

Mess and bunk tents	2	$ 104.86
Outhouse tents	2	3.92
Tent cover, 20 x 30, with poles	1	42.14
Canvas fences	2	7.35
Cots	18	16.02
Pads for cots	15	18.75
Comforters	18	17.64
Pillows	18	8.82
Pillow-cases	18	2.25
B blankets	18	28.62
G blankets	18	10.62
Towels	12	1.25
Dishes, cutlery, pots, kettles, cooking utensils and other camp equipment	..	98.93
		$ 361.17

In addition to the above the commissioners own the following:

	Cost
Carpenters' tools	$ 32.73
Miscellaneous	131.96
Engineering and office equipment	1,025.97
Cement testing apparatus	55.05

The total original cost of the plant and property was $33,185.38. The depreciation for 1909 was placed at $3,850.88 and the depreciation for 1910 at 15% was placed at $4,400.18.

Road-Making Plant. The following is the approximate cost of a road-making plant, operating in the State of Missouri, figures of 1910.

Six dump cars and 200 ft. of trackage for use in quarry	$ 600.00
Crusher, 11 in. by 18 in., 25 tons per hour capacity	775.00
Bin — 3 sections	350.00
Elevator — 14 ft.	150.00
Revolving screen — 30 in., 4 ft. long	125.00
Two traction engines — 20 hp.	3,000.00
One 10-ton steam roller — 15 hp.	2,500.00
One 6-horse grader	200.00
Six dump wagons — 1½ cu. yd.	600.00
Twelve hand drills, 12 picks, 12 crowbars, 24 shovels	50.00
One road plow, $5 — 11 in. cut, 4 horse	20.00
Six wheelers, No. 2 — 12 cu. ft. capacity	200.00
Six drags, No. 2 — 4½ cu. ft. capacity	40.00
Sprinkling wagon No. 3 — 600 gal. capacity	325.00
	$8,935.00

Moving the plant 12 miles overland and setting it up at a new quarry cost $500. After the move, the plant, new to begin with, which had only been used to build four miles of 16-ft. roadbed. cost $200 for new fittings and repairs, which, for six months' use, is an annual depreciation on plant of 5% of the cost.

SECTION 80

ROLLERS

A reversible horse roller of the latest type, with two rolls having a total face width of 5 ft., is manufactured in sizes from 3½ to 10 tons of ½-ton variation and is sold for $165 per ton. The diameter of the rolls varies from 4½ ft. on the lightest rollers to 6 ft. on the heaviest.

Hand Rollers

Diameter (in.)	Length (in.)	Sections (in.)	Weight (lb.)	Price
15	24	3	200	$16
20	24	3	300	24
20	24	2	300	24
24	24	2	450	35
24	24	3	450	35

Rollers 50 to 300 lb. heavier than any of the above, 8 ct. per lb. extra.

Fig. 270. Cast Iron Reversible Road Roller.

Steam Rollers are made in two types: the macadam or three wheel type and the tandem. The macadam type is generally made in two sizes; the average cost of the 10 ton size is $4,250, and the 12 ton $4,800. The average prices for the tandem type are $1,700 for the 2½ ton size, $2,875 for the 5 ton size, $3,500 for the 8 ton size, and $4,200 for the 9 ton size.

A simple road roller, steam driven, that may be converted into a hauling engine and designed so that the engine can be used for stationary work, has a rolling surface width of 6 ft. 6 in. It has

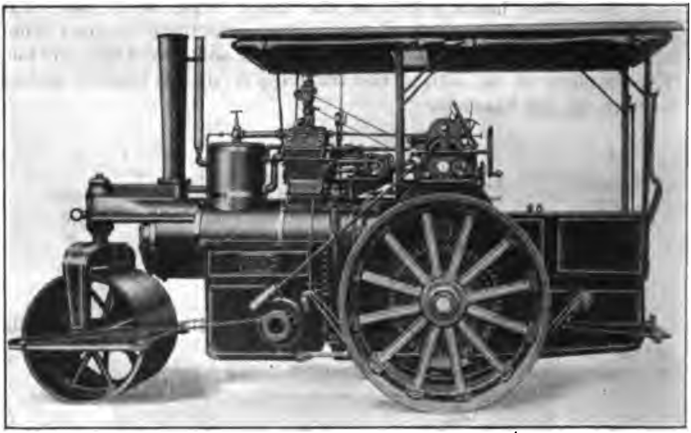


Fig. 271. Ten Ton Steam Type Roller.

a short wheel base that allows short turns, differential gear for two wheel drive and a mechanical steering device. It is made in two sizes. The 10 ton size costs $4,000 and the 12 ton size $4,500 f. o. b. Wisconsin.

Cost of Maintenance and Operation of Steam Rollers. The following table shows the cost of maintenance and operation of the six steam road rollers owned by the city of Grand Rapids, Mich. The figures have been taken from the annual report of the City Engineer for the fiscal year ending March 31, 1911.

COST OF MAINTENANCE AND OPERATION OF STEAM ROAD ROLLERS

Maintenance:	No. 1 Roller	No. 2 Roller	No. 3 Roller	No. 4 Roller	No. 5 Roller	No. 6 Roller
Labor, shop	$ 117.37	$ 106.72	$ 149.67	$ 116.67	$ 25.11	$ 99.61
Repair parts	332.94	126.46	224.16	128.12	63.57	43.19
Telephone	2.00	1.40	1.15	1.30	1.00	1.05
Engineering	2.00	6.00	3.00	2.00	2.00	3.00

Maintenance:	No. 1 Roller	No. 2 Roller	No. 3 Roller	No. 4 Roller	No. 5 Roller	No. 6 Roller
Carfare	.25	.60	.15	.20	.20	.15
Belting	3.18	....	1.14	.84	1.82	1.27
Wagon repair	4.25	4.70	....	.40	......	6.50
Chains and hooks	3.36	....	....	....	......	3.37
Telegrams	.49	....	....	....	......	.64
Paint	.75	1.35	....	....	......	....
Express	.15	.25	....	....	......	....
Hose	....	5.87	....	....	......	....
Roller repair	....	27.18	11.50	....	......	....
New wheels	....	197.10	....	....	......	....
Oilers	....	1.60	....	....	2.70	....
Canvas covers	....	....	22.44	....	......	....
Rolling flues	....	....	7.90	4.50	1.60	....
Seat and spring	....	....	....	1.05	......	....
Hand hole clamps	....	....	....	.25	......	....
Padlocks and chains.	....	....	....	....	.60	.75
Brackets	....	....	....	....	2.10	....
Total	$ 466.74	$ 479.23	$ 421.11	$ 255.33	$100.90	$ 159.53
Operation:						
Labor, running	$ 807.48	$ 822.40	$ 783.60	$ 835.05	$390.00	$ 831.30
Labor, cleaning	34.00	34.00	32.00	58.00	3.50	6.00
Tools	1.34	4.19	.26	1.40	2.08	1.85
Coal	347.32	356.17	316.73	215.01	178.46	278.86
Kindling	25.00	25.00	21.50	15.60	11.50	19.50
Oil	20.47	25.80	20.61	17.68	10.25	14.90
Waste	2.20	3.87	2.48	2.07	2.46	2.46
Cartage	4.73	7.18	3.64	.25	2.40	2.00
Packing	1.25	2.60	2.55	....	.75	....
Boiler compound	6.24	7.80	4.68	1.92	......	3.90
Matches	.13	.05	.04	....	......	....
Lanterns and globes.	1.26	.80	....	2.33	1.90	1.26
Grease	....	.37	.72	.11	......	.18
Candles	....	.06	.06	.06	......	.27
Total Op. and Maint..	$1,718.16	$1,769.52	$1,609.98	$1,404.71	$704.00	$1,322.01
Total Operation	$1,251.42	$1,290.29	$1,188.87	$1,149.38	$603.10	$1,162.48

Repairs on two rollers of the convertible type during the first season of operation cost $86.00; $77.00 of this was for one roller which had not been kept in good shape and $9.00 was for the other roller, which was operated by a particularly efficient engineer.

In 1905, on 16 steam rollers belonging to the Massachusetts Highway Commissioners, each roller averaged 90.3 working days per year and the average cost of repairs was $1.12 per day per roller.

In 1906 the total days' work of 16 rollers under the control of the Massachusetts Highway Commission was 1,719.5, an average of 107.5 days per roller per season. Total cost for maintenance of these rollers was as follows:

$1,725.00 for practically rebuilding two rollers which had been in active service about ten years, and an average of $53.14 each on 14 others. The total cost of repairs on 16 rollers was, therefore, $2,468.96, or an average of $154.31 each.

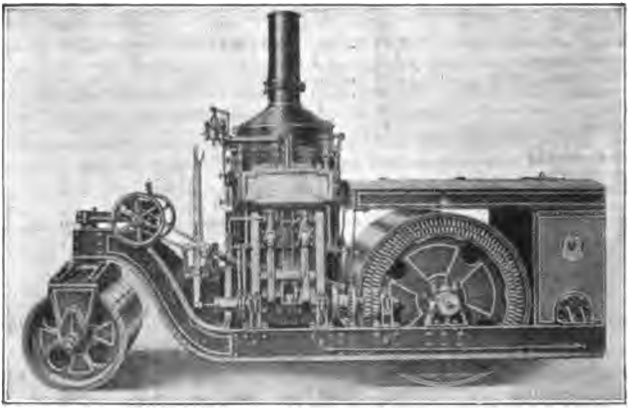


Fig. 272. 5-Ton Tandem Roller.

In 1907 the above 16 rollers did 1,808 days' work, an average of 113 days per roller per season. Two rollers were practically rebuilt for $1,888.00 and ordinary repairs on the 14 others cost $651.69. The total average cost was, therefore, $158.73.

Mr. Thomas Aitken, the English author, states that the repairs on a roller up to the 14th year were small, with the exception

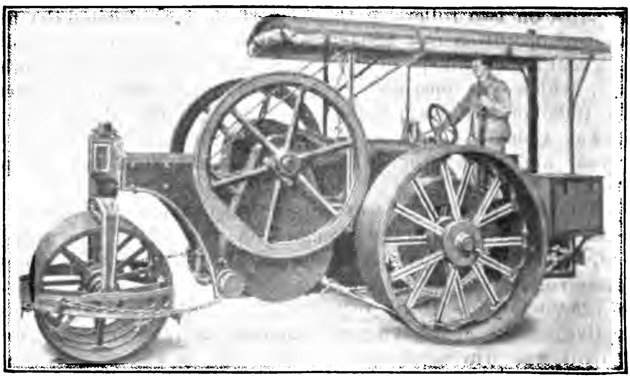


Fig. 273. American Motor Road Roller.

of new driving wheels and repairs to the firebox and tubes. All repairs amounted to an average of $55.00 a year. At this time heavy repairs, costing $850.00, were needed. The total cost per year during a life of 25 years, of 100 working days each, is $105.00, or 5% of the first cost. The rear wheels of a roller lasted 7 years, during which time they consolidated 60,000 tons of road metal.

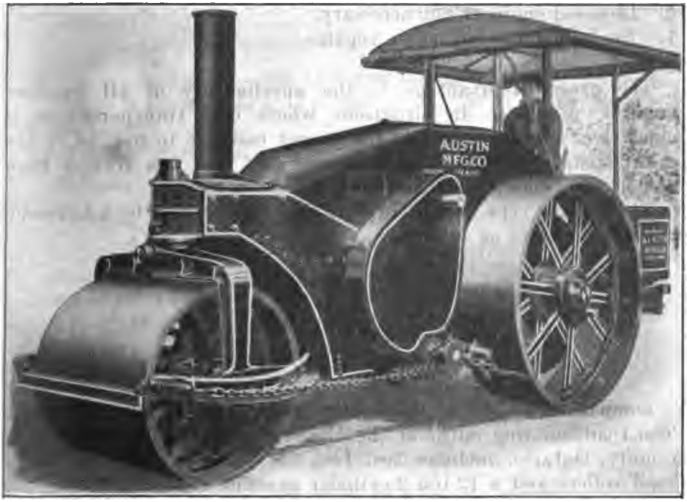


Fig. 274. Ten Ton Two-Cylinder Kerosene Motor Roller.

Motor Road Roller of the tandem or three wheel type, operated by gasoline or kerosene is made in five sizes as follows:

Size in tons	Net weight in lb.	Price f. o. b. Chicago
7	14,690	$4,000
8	17,500	4,200
10	23,775	4,400
12	25,710	5,000
15	32,200	5,700

The 10-ton or larger sizes will haul a scarifier, grader or road plow.

This machine has a trussed frame made of heavy steel plates, which carries the engine, thereby eliminating a great defect found in steam rollers, that of making the boiler act as the frame.

Some of the advantages over the steam roller claimed for this machine by the manufacturers are:

1. No smoke, steam, sparks or soot blowing about.
2. No daily water supply needed.
3. No daily coal supply needed.
4. No nightly banking of fires.
5. No time lost raising steam.
6. Licensed engineer not necessary.
7. No laying up for boiler repairs.

The great disadvantage is the unreliability of all gasoline engines. However, in situations where coal transportation is expensive, a motor roller is the proper machine to use, as it has a tank capacity for 10 to 20 hours' fuel, and can trail a tank wagon carrying a month's supply.

The tandem type is built in four sizes, is operated by a kerosene engine and costs as follows:

Size in tons	Net weight in lb.	Price f. o. b. Chicago
5	10,920	$3,700
6	12,900	3,900
7	14,655	4,400
8	16,655	4,600

Comparative Cost of Operating Steam and Gasoline Rollers. The road building outfit of the Highway Commissioners of York County, Ontario, includes two 12½-ton and two 11½-ton steam road rollers and a 12-ton 2-cylinder gasoline road roller. In the report of the Commission covering the year 1912 Mr. E. A. James, Chief Engineer of the Commission, gives the following figures to show the cost as nearly as can be judged of operation of the steam and gasoline machinery, both rollers working under similar conditions:

Cost of Operating Steam Roller

For 10 Hours' Rolling.

Fuel —	
Kindling wood	$0.05
Coal, 380 lb. at $6.85 per ton	1.30
Water —	
600 gal., hauling 3 hr. at 50 ct. per hr.	1.50
Oil, etc.	0.05
Engineer — 11½ hours at 30 ct. per hour	3.45
Total	$6.35

For 10 Hours' Spiking and Scarifying.

Fuel —	
Kindling wood	$0.05
Coal, 480 lb. at $6.85 per ton	1.64
Water —	
800 gal., hauling	2.00
Oil	0.05
Engineer — 11½ hours at 30 ct.	3.45
Total	$7.19

Cost of Operating a Gasoline Roller

For 10 Hours' Rolling.

Fuel — 12 gal. gasoline at 15 ct. per gal.	$1.80
Water —	
Cooling, quarter hour	0.12½
Oil	0.07
Engineer — 10¼ hours at 30 ct.	3.07½
Total	$5.07

For 10 Hours' Spiking and Scarifying.

Fuel — 20 gal. gasoline at 15 ct. per gal.	$3.00
Water —	
For cooling	0.15
Oil	0.07
Engineer — 10¼ hours at 30 ct.	3.07
Total	$6.29

SECTION 81

ROPE

Wire Rope. The first wire ropes were constructed largely of iron wire, but the modern wire rope is made of variously manipulated and treated carbon steels. The usual classifications are:

Iron.

Crucible steel.

Extra strong crucible steel.

Plow steel.

The so-called Iron is a mild Bessemer or Basic steel of from 60,000 to 100,000 lb. per square inch tensile strength; the Crucible Steel is a carbon open hearth steel of from 160,000 to 200,000 lb. per square inch tensile strength; the Extra Strong Crucible Steel ranges in strength from 200,000 to 240,000 lb. per square inch, and the Plow Steel ranges from about 240,000 lb. per square inch up.

Up to May 1, 1909, the breaking strengths of wire rope manufactured in the United States were based upon the strength of the individual wires in the rope, but since that time all manufacturers have adopted strength figures compiled from results of actual tests.

There are a vast number of arrangements possible in wire rope construction, but the usual construction is one in which a number of wires are built up on a hemp core.

Discounts to apply to the following, which were in effect in January, 1920, are as follows:

Plow Steel

Standard	List price less 35%—10%
Extra strong	List price less 30%—10%

Crucible Cast Steel

Standard	List price less 22%—10%
Extra strong	List price less 30%—10%

Standard Iron Hoisting Rope

6 by 19	List price less 5%—10%

Galvanized Steel Running Rope

6 by 12, 6 by 24, 7 hemp cores	List price less 7 %—10%

Galvanized Steel Rigging Rope

6 by 7 ....List price less 7%—10%

Galvanized Extra Flexible Hoisting and Mooring Lines

6 by 37. Net

Galvanized Iron Rigging Rope

6 by 7. Net

Standard Iron Tiller Rope

6 by 6 by 7 ....List price less 5%—10%

Non-Spinning Rope

18 by 7 ....List price less 10%— 5%

Transmission, Haulage or Standing Rope. Six strands of seven wires each built on a hemp core make what is known as haulage rope. This is one of the oldest types and was formerly largely used for power transmission, but now its use is largely confined to mines, for slope haulage systems embodying endless and tail rope applications, on coal docks, in oil well drillings, and, when galvanized, as guys for derricks. It will stand considerable abrasion and rough handling, but is stiff, and its use, therefore, is limited.

PRICES TRANSMISSION, HAULAGE OR STANDING ROPE

(Standard Strengths, Adopted May 1, 1910)

6-Strands — 7 Wires to the Strand — One Hemp Core

(See discount list on page 630)

Swedes Iron

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
11	$0.51	1½	4¾	3.55	32	6.4	16
12	.43	1⅜	4¼	3	28	5.6	15
13	.36	1¼	4	2.45	23	4.6	13
14	.30	1⅛	3½	2	19	3.8	12
15	.24	1	3	1.58	15	3	10.5
16	.18½	⅞	2¾	1.20	12	2.4	9
17	.14	¾	2¼	.89	8.8	1.7	7.5
18	.12	11/16	2⅛	.75	7.3	1.5	7.25
19	.10	⅝	2	.62	6	1.2	7
20	.08¼	9/16	1¾	.50	4.8	.96	6
21	.06½	½	1½	.39	3.7	.74	5.5
22	.05½	7/16	1¼	.30	2.6	.52	4.5
23	.04½	⅜	1⅛	.22	2.2	.44	4
24	.03¾	5/16	1	.15	1.7	.34	3.5
25	.03¼	9/32	⅞	.12½	1.2	.24	3

Crucible Cast Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
11	$0.60	1½	4¾	3.55	63	12.6	11
12	.51	1⅜	4¼	3	53	14.6	10
13	.43	1¼	4	2.45	46	9.2	9
14	.35	1⅛	3½	2	37	7.4	8
15	.29	1	3	1.58	31	6.2	7
16	.22½	⅞	2¾	1.20	24	4.8	6
17	.17	¾	2¼	.89	18.6	3.7	5
18	.14½	11/16	2⅛	.75	15.4	3.1	4¾
19	.12	⅝	2	.62	13	2.6	4½
20	.10	9/16	1¾	.50	10	2	4
21	.08	½	1½	.39	7.7	1.5	3½
22	.06½	7/16	1¼	.30	5.5	1.1	3
23	.05½	⅜	1⅛	.22	4.6	.92	2¾
24	.04½	5/16	1	.15	3.5	.70	2¼
25	.04	9/32	⅞	.12½	2.5	.50	1¾

Extra Strong Crucible Cast Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
11	$0.75	1½	4¾	3.55	73	14.6	11
12	.64	1⅜	4¼	3	63	12.6	10
13	.53	1¼	4	2.45	54	10.8	9
14	.44	1⅛	3½	2	43	8.6	8
15	.35	1	3	1.58	35	7	7
16	.27	⅞	2¾	1.20	28	5.6	6
17	.20	¾	2¼	.89	21	4.2	5
18	.17	11/16	2⅛	.75	16.7	3.3	4¾
19	.14¼	⅝	2	.62	14.5	2.9	4½
20	.12	9/16	1¾	.50	11	2.2	4
21	.09½	½	1½	.39	8.85	1.8	3½
22	.07½	7/16	1¼	.30	6.25	1.25	3
23	.06	⅜	1⅛	.22	5.25	1.05	2¾
24	.05½	5/16	1	.15	3.95	.79	2¼
25	.05	9/32	⅞	.12½	2.95	.59	1¾

Plow Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
11	$0.90	1½	4¾	3.55	82	16.4	11
12	.76	1⅜	4¼	3	72	14.4	10
13	.62	1¼	4	2.45	60	12	9
14	.51	1⅛	3½	2	47	9.4	8
15	.41	1	3	1.58	38	7.6	7
16	.32	⅞	2¾	1.20	31	6.2	6
17	.24½	¾	2¼	.89	23	4.6	5
18	.21	11/16	2⅛	.75	18	3.6	4¾
19	.17½	⅝	2	.62	16	3.2	4½
20	.14½	9/16	1¾	.50	12	2.4	4
21	.11½	½	1½	.39	10	2	3½
22	.09	7/16	1¼	.30	7	1.4	3
23	.06¾	⅜	1⅛	.22	5.9	1.2	2¾
24	.06	5/16	1	.15	4.4	.88	2¼
25	.05½	9/32	⅞	.12½	3.4	.68	1¾

Monitor Plow Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
11	$1.05	1½	4¾	3.55	90	18	11
12	.88	1⅜	4¼	3	79	16	10
13	.72	1¼	4	2.45	67	13	9
14	.58	1⅛	3½	2	52	10	8
15	.48	1	3	1.58	42	8.4	7
16	.37	⅞	2¾	1.20	33	6.6	6
17	.28½	¾	2¼	.89	25	5	5
18	.24½	11/16	2⅛	.75	20	4	4¾
19	.20½	⅝	2	.62	17½	3.5	4½
20	.17	9/16	1¾	.50	13	2.6	4
21	.13½	½	1½	.39	11	2.2	3½
22	.11½	7/16	1¼	.30	7¾	1.5	3
23	.08¾	⅜	1⅛	.22	6½	1.3	2½

All ropes not listed herein and composed of more than 7 and less than 19 wires to the strand, with the exception of 6 x 8, take 19 wire list.

Standard Hoisting Rope. Six strands of nineteen wires each make a hoisting rope which has a wider and more varied application than any other type. It combines both flexibility and wearing service and is used in mining shafts, for operating the cages and elevators, derricks, coal and ore handling machines, logging, dredges, skip hoists, conveyors, etc.

Prices Standard Hoisting Rope

(Standard Strengths, Adopted May 1, 1910)

6 Strands — 19 Wires to the Strand — One Hemp Core

Swedes Iron

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
00	$1.70	2¾	8⅝	11.95	111	22.2	17
0	1.40	2½	7⅞	9.85	92	18.4	15
1	1.17	2¼	7⅛	8	72	14.4	14
2	.95	2	6¼	6.30	55	11	12
2½	.88	1⅞	5¾	5.55	50	10	12
3	.80	1¾	5½	4.85	44	8.8	11
4	.65	1⅝	5	4.15	38	7.6	10
5	.57	1½	4¾	3.55	33	6.6	9
5½	.49	1⅜	4¼	3	28	5.6	8.5
6	.40	1¼	4	2.45	22.8	4.56	7.5
7	.33	1⅛	3½	2	18.6	3.72	7

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
8	.26	1	3	1.58	14.5	2.90	6
9	.20	⅞	2¾	1.20	11.8	2.36	5.5
10	.16	¾	2¼	.89	8.5	1.70	4.5
10¼	.12	⅝	2	.62	6	1.20	4
10½	.10	9/16	1¾	.50	4.7	.94	3.5
10¾	.08½	½	1½	.39	3.9	.78	3
10a	.07½	7/16	1¼	.30	2.9	.58	2.75
10b	.07	⅜	1⅛	.22	2.4	.48	2.25
10c	.06¾	5/16	1	.15	1.5	.30	2
10d	.06½	¼	¾	.10	1.1	.22	1.50

Crucible Cast Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
00.	$2.10	2¾	8⅝	11.95	211	42.2	11
0	1.75	2½	7⅞	9.85	170	34	10
1	1.44	2¼	7⅛	8	133	26.6	9
2	1.16	2	6¼	6.30	106	21.2	8
2½	1.02	1⅞	5¾	5.55	96	19	8
3	.90	1¾	5½	4.85	85	17	7
4	.77	1⅝	5	4.15	72	14.4	6.5
5	.66	1½	4¾	3.55	64	12.8	6
5½	.56	1⅜	4¼	3	56	11.2	5.5
6	.46	1¼	4	2.45	47	9.4	5
7	.38	1⅛	3½	2	38	7.6	4.5
8	.31	1	3	1.58	30	6	4
9	.24	⅞	2¾	1.20	23	4.6	3.5
10	.19	¾	2¼	.89	17.5	3.5	3
10¼	.14	⅝	2	.62	12.5	2.5	2.5
10½	.12	9/16	1¾	.50	10	2	2.25
10¾	.11	½	1½	.39	8.4	1.68	2
10a	.10	7/16	1¼	.30	6.5	1.30	1.75
10b	.09½	⅜	1⅛	.22	4.8	.96	1.50
10c	09¼	5/16	1	.15	3.1	.62	1.25
10d	.09	¼	¾	.10	2.2	.44	1

Extra Strong Crucible Cast Steel

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
00	$2.55	2¾	8⅝	11.95	243	48.6	11
0	2.10	2½	7⅞	9.85	200	40	10
1	1.70	2¼	7⅛	8	160	32	9
2	1.34	2	6¼	6.3	123	24.6	8
2½	1.25	1⅞	5¾	5.55	112	22.4	8
3	1.10	1¾	5½	4.85	99	19.8	7
4	.94	1⅝	5	4.15	83	16.6	6.5
5	.80	1½	4¾	3.55	73	14.6	6
5½	.68	1⅜	4¼	3	64	12.8	5.5
6	.56	1¼	4	2.45	53	10.6	5
7	.46	1⅛	3½	2	43	8.6	4.5
8	.37	1	3	1.58	34	6.80	4
9	.29	⅞	2¾	1.20	26	5.20	3.5
10	.22	¾	2¼	.89	20.2	4.04	3
10¼	.16½	⅝	2	.62	14	2.80	2.5

Trade Number	List Price per Ft.	Diameter in In.	Circumference in In.	Approx. Wt. per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in tons of 2,000 Lb.	Diam. of Drum or Sheave in Ft. Advised
10½	.14	9/16	1¾	.50	11.2	2.24	2.25
10¾	.12½	½	1½	.39	9.2	1.84	2
10a	11½	7/16	1¼	.30	7.25	1.45	1.75
10b	.11	⅜	1⅛	.22	5.30	1.06	1.50
10c	.10¾	5/16	1	.15	3.50	.70	1.25
10d	.10½	¼	¾	.10	2.43	.49	1
			Plow Steel				
00	$3 00	2¾	8⅝	11.95	275	55	11
0	2.50	2½	7⅞	9.85	229	46	10
1	2.00	2¼	7⅛	8	186	37	9
2	1.58	2	6¼	6.3	140	28	8
2½	1.46	1⅞	5¾	5.55	127	25	8
3	1.30	1¾	5½	4.85	112	22	7
4	1.08	1⅝	5	4.15	94	19	6.5
5	93	1½	4¾	3.55	82	16	6
5½	.79	1⅜	4¼	3	72	14	5.5
6	.65	1¼	4	2.45	58	12	5
7	.54	1⅛	3½	2	47	9.4	4.5
8	.43	1	3	1.58	38	7.6	4
9	.34	⅞	2¾	1.20	29	5.8	3.5
10	.26	¾	2¼	.89	23	4.6	3
10¼	.19	⅝	2	.62	15.5	3.1	2.5
10½	.16	9/16	1¾	.50	12.3	2.4	2.25
10¾	.14	½	1½	.39	10	2	2
10a	.13	7/16	1¼	.30	8	1.6	1.75
10b	.12½	⅜	1⅛	.22	5.75	1.15	1.50
10c	.12¼	5/16	1	.15	3.8	.76	1.25
10d	.12	¼	¾	.10	2.65	.53	1
			Monitor Plow Steel				
00	$3.45	2¾	8⅝	11.95	315	63	11
0	2.80	2½	7⅞	9.85	263	53	10
1	2.50	2¼	7⅛	8	210	42	9
2	1.85	2	6¼	6.30	166	33	8
2½	1.75	1⅞	5¾	5.55	150	30	8
3	1.60	1¾	5½	4.85	133	27	7
4	1.30	1⅝	5	4.15	110	22	6½
5	1.10	1½	4¾	3.55	98	20	6
5½	.90	1⅜	4¼	3	84	17	5½
6	.75	1¼	4	2.45	69	14	5
7	.62	1⅛	3½	2	56	11	4½
8	.50	1	3	1.58	45	9	4
9	.39	⅞	2¾	1.20	35	7	3½
10	.31	¾	2¼	.89	26.3	5.3	3
10¼	.22½	⅝	2	.62	19	3.8	2½
10½	.19	9/16	1¾	.50	14.5	2.9	2¼
10¾	.17	½	1½	.39	12 1	2.4	2
10a	.15½	7/16	1¼	.30	9.4	1.9	1¾
10b	.14½	⅜	1⅛	.22	6.75	1.35	1½
10c	.13½	5/16	1	.15	4.50	.9	1¼
10d	.13	¼	¾	.10	3.15	.63	1

All ropes not listed herein and composed of strands made up of more than 19 and less than 37 wires, take 37 wire list.

"Where the requirements are severe, we recommend Monitor rope. It is the strongest and most efficient rope produced.

"It is indispensable for heavy dredging, logging, stump pulling, derricks, coal and ore hoisting service."

Extra Flexible Steel Hoisting Rope. Eight strands of nineteen wires each make an extra flexible rope whose application is confined to a somewhat limited field. It is used on derricks and in similar places where sheaves are of very small diameter, and in flexibility is about on a par with the 6 x 37 construction, differing only in the fact that it is not quite as strong, owing to its large hemp center.

List Prices Extra Flexible Steel Hoisting Rope
(Standard Strengths Adopted May 1, 1910)

Eight Strands — 19 Wires to the Strand — One Hemp Core

List price per foot	Diameter in inches	Circumference in inches	Approximate weight per foot	Approximate strength in tons of 2,000 lb.	Proper working load in tons of 2,000 lb.	Diameter of drum or sheave in ft. Advised
Crucible Cast Steel						
$0.73	1½	4¾	3.19	58	11.6	3.75
.62	1⅜	4¼	2.70	51	10.2	3.5
.51	1¼	4	2.20	42	8.4	3.2
.42	1⅛	3½	1.80	34	6.8	2.83
.34	1	3	1.42	26	5.2	2.5
.27	⅞	2¾	1.08	20	4	2.16
.21	¾	2¼	.80	15.3	3.06	1.83
.16	⅝	2	.56	10.9	2.18	1.75
.14	9/16	1¾	.45	8.7	1.74	1.5
.12	½	1½	.35	7.3	1.46	1.33
.11	7/16	1¼	.27	5.7	1.14	1.16
.10½	⅜	1⅛	.20	4.2	.84	1
.10¼	5/16	1	.13	2.75	.55	.83
.10	¼	¾	.09	1.80	.36	.75
Extra Strong Crucible Cast Steel						
$0.88	1½	4¾	3.19	66	13	3.75
.75	1⅜	4¼	2.70	57	11	3.5
.62	1¼	4	2.20	47	9.4	3.2
.51	1⅛	3½	1.80	38	7.6	2.83
.41	1	3	1.42	29.7	5.9	2.5
.32	⅞	2¾	1 08	23	4.6	2.16
.25	¾	2¼	.80	17.6	3.5	1.83
.18½	⅝	2	.56	12.4	2.5	1.75
.16	9/16	1¾	.45	10.1	2	1.5

List Price per Foot.	Diameter in Inches.	Circumference in Inches.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper working Load in Tons of 2,000 Lb.	Diameter of Drum or Sheave in Ft. Advised
.14	½	1½	.35	8	1.6	1.33
.13	7/16	1¼	.27	6.30	1.26	1.16
.12¼	⅜	1⅛	.20	4.66	.93	1
.12	5/16	1	.13	3.05	.61	.83
.11¾	¼	¾	.09	2.02	.40	.75
			Plow Steel			
$1.03	1½	4¾	3.19	74	14.8	3.75
.87	1⅜	4¼	2.70	64	12.8	3 5
.72	1¼	4	2.20	52	10.4	3.2
.60	1⅛	3½	1.80	43	8 6	2.83
.48	1	3	1.42	33	6.6	2.5
.38	⅞	2¾	1.08	26	5.2	2.16
.29	¾	2¼	.80	20	4	1.83
.21	⅝	2	.56	14	2.8	1.75
.18	9/16	1¾	.45	11.6	2.32	1.50
.16	½	1½	.35	8.7	1.74	1.33
.15	7/16	1¼	.27	6.90	1.38	1.16
.14	⅜	1⅛	.20	5.12	1.02	1
.13½	5/16	1	.13	3.35	.67	.83
.13¼	¼	¾	.09	2.25	.45	.75
			Monitor Plow Steel			
$1.19	1½	4¾	3.19	80	16	3.75
.98	1⅜	4¼	2.70	68	13	3.5
.82	1¼	4	2.20	56	11	3.2
.68	1⅛	3½	1.80	46	9.2	2 83
.55	1	3	1.42	36	7.2	2.5
.43	⅞	2¾	1.08	28	5.6	2.15
.34	¾	2¼	.80	22	4.4	1.83
.25	⅝	2	.56	15	3	1.75
.22	9/16	1¾	.45	12	2.4	1.5
.19	½	1½	.35	9.5	1.9	1.33

Special Flexible Hoisting Rope. Six strands of thirty-seven wires each make a special flexible rope which is largely used on electric travel cranes and for large dredge ropes. It permits the use of fairly small sheaves and bends over them easily. This rope comes in diameters of ½-in. variation, but is much better in the larger size than the extra strong on account of the smaller hemp core.

List Prices Special Flexible Hoisting Ropes
(Standard Strengths, Adopted May 1, 1910)

Six Strands — 37 Wires to the Strand — One Hemp Core

Crucible Cast Steel

List Price per Foot.	Diameter in Inches.	Circumference in Inches.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper working Load in Tons of 2,000 Lb.	Diameter of Drum or Sheave in Ft. Advised
$2.30	2¾	8⅝	11.95	200	40	...
1.92	2½	7⅞	9.85	160	32	...
1.60	2¼	7⅛	8	125	25	...
1.35	2	6¼	6.30	105	21	...
1.05	1¾	5½	4.85	84	17	...
.89	1⅝	5	4.15	71	14	...
.79	1½	4¾	3.55	63	12	3.75
.65	1⅜	4¼	3	55	11	3.5
.55	1¼	4	2.45	45	9	3.2
.46	1⅛	3½	2	34	7	2.83
$ .37	1	3	1.58	29	6	2.5
.28	⅞	2¾	1.20	23	5	2.16
.23	¾	2¼	.89	17.5	3.5	1.83
.18	⅝	2	.62	11.2	2.2	1.75
.15	9/16	1¾	.50	9.5	1.9	1.5
.13	½	1½	.39	7.25	1.45	1.33
.12½	7/16	1¼	.30	5.5	1.1	1.16
.12	⅜	1⅛	.22	4.2	.84	1

Extra Strong Crucible Cast Steel

List Price per Foot.	Diameter in Inches.	Circumference in Inches.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper working Load in Tons of 2,000 Lb.	Diameter of Drum or Sheave in Ft. Advised
$2.80	2¾	8⅝	11.95	233	47	...
2.35	2½	7⅞	9.85	187	37	...
1.90	2¼	7⅛	8	150	30	...
1.55	2	6¼	6.30	117	23	...
1.28	1¾	5½	4.85	95	19	...
1.07	1⅝	5	4.15	79	16	...
.95	1½	4¾	3.55	71	14	3.75
.78	1⅜	4¼	3	61	12	3.5
.65	1¼	4	2.45	50	10	3.20
.55	1⅛	3½	2	39	8	2.83
.44	1	3	1.58	32	6.4	2.5
.34	⅞	2¾	1.20	25	5	2.16
.27	¾	2¼	.89	19	3.8	1.83
.21	⅝	2	.62	12.6	2.5	1.75
.17½	9/16	1¾	.50	10.5	2.1	1.5
.15	½	1½	.39	8.25	1.65	1.33
.14	7/16	1¼	.30	6.35	1.27	1.16
.13	⅜	1⅛	.22	4.65	.93	1

Plow Steel

List Price per Foot.	Diameter in Inches.	Circumference in Inches.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper working Load in Tons of 2,000 Lb.	Diameter of Drum or Sheave in Ft. Advised
$3.30	2¾	8⅝	11.95	265	53	...
2.75	2½	7⅞	9.85	214	43	...
2.20	2¼	7⅛	8	175	35	...
1.80	2	6¼	6.30	130	26	...
1.50	1¾	5½	4.85	108	22	...

List Price per Foot.	Diameter in Inches.	Circumference in Inches.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper working Load in Tons of 2,000 Lb.	Diameter of Drum or Sheave in Ft. Advised
1.25	1⅝	5	4.15	90	18	...
1.10	1½	4¾	3.55	80	16	3.75
.91	1⅜	4¼	3	68	14	3.5
.75	1¼	4	2.45	55	11	3.2
.64	1⅛	3½	2	44	9	2.83
.51	1	3	1.58	35	7	2.5
.40	⅞	2¾	1.20	27	5	2 16
.31	¾	2¼	.89	21	4	1.83
.24	⅝	2	.62	14	3	1.75
.20	9/16	1¾	.50	11.5	2.3	1.5
.17	½	1½	.39	9.25	1.85	1.33
.16	7/16	1¼	.30	7.2	1.4	1.16
.15	⅜	1⅛	.22	5.1	1	1
		Monitor Plow Steel				
$3.75	2¾	8⅝	11.95	278	55	...
3.15	2½	7⅞	9.85	225	45	...
2.50	2¼	7⅛	8	184	37	...
2 10	2	6¼	6 30	137	27	...
1.75	1¾	5½	4.85	113	23	...
1.45	1⅝	5	4.15	95	19	...
1 25	1½	4¾	3.55	84	17	3.75
1.05	1⅜	4¼	3	71	14	3.50
.86	1¼	4	2 45	58	11	3 20
.75	1⅛	3½	2	46	9.2	2 83
.59	1	3	1.58	37	7.4	2.50
.46	⅞	2¾	1.20	29	5.8	2.16
.36	¾	2¼	.89	23	4.6	1.83
.27	⅝	2	.62	16	3.2	1.75
.23	9/16	1¾	.50	12½	2.5	1.50
.20	½	1½	.39	9.75	1.9	1.33
18½	7/16	1¼	.30	7.50	1.5	1.15
.17½	⅜	1⅛	.22	5.30	1.06	1

Ropes composed of strands made up of more than 37 wires add 10% to list price of 6 x 37.

Tiller Rope or Hand Rope. The 6 x 6 x 7 construction is known as tiller rope and is the most flexible rope manufactured. Its first applications were to the steering gear of boats, but its greatest application today is for hand rope on elevators. This is made up of six strands of forty-two wires each and seven hemp cores and comes in diameters of 1/16-in. variation.

Prices Tiller Rope or Hand Rope

— List Price per Foot — Iron	Crucible Cast Steel	Diameter in Inches	Circumference in Inches	Approx. Weight per Foot Lb.
$0.33	$0.43	1	3	1.10
.27	.36	⅞	2¾	.84
.22	.30	¾	2¼	.62
.17	.24	⅝	2	.43
.14	.20	9/16	1¾	.35
.11½	.17	½	1½	.28
.10	.15	7/16	1¼	.21
.09	.14	⅜	1⅛	.16
.08	.12½	5/16	1	.11
.07½	.11	¼	¾	.07

The wires are very fine. Care should be taken not to subject it to much abrasive wear.

It is used to a limited extent for steering lines on yachts and motor boats. Galvanized Crucible Cast Steel Yacht Rope, 6 strands, 19 wires to the strand, 1 hemp core, is preferred by many for motor boats.

⅜ and ½-in. diameter Iron Tiller or Hand Rope is used for starting and stopping elevators. This rope is also called Elevator Shipper Rope.

Tiller Rope of tinned or galvanized iron or steel is furnished if required.

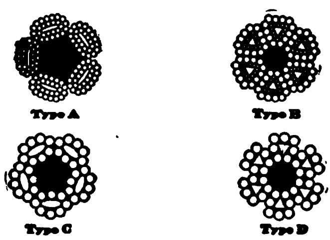


Fig. 275.

Flattened Strand Rope. Flattened Strand Ropes are used for heavy derricks, hoists, etc., where great flexibility and long life are required. They are made in a variety of types and steels. Those with an odd number of oval strands are particularly difficult to splice. The best type is that composed of 6 triangular shaped strands of wire, each strand made up of 12 large outside steel wires, 1 large triangular inside iron wire, with 12 smaller round steel wires between. This comes in the various iron and steels, but we give prices and capacities of Monitor plow steel rope only.

Flattened Strand Rope

Type A — 5 Strands, 28 Wires to the Strand, One Hemp Core
Type B — 6 Strands, 25 Wires to the Strand, One Hemp Core

		Type A			Type B			
Diameter in Inches	List Price per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Approx. Weight per Foot	Diameter of Drum or Sheave in Feet Advised
2¼	$2.85	210	42	8.00	231	46.2	9.20	12
2	2.25	166	33.2	6.30	183	36.6	7.25	11
1¾	2.08	133	26.6	4.85	146	29.2	5.60	9
1⅝	1.56	110	22	4.15	121	24.2	4.75	8½
1½	1.37	98	10.6	3.55	108	21.6	4.00	8
1⅜	1.12	84	16.8	3.00	92	18.4	3.45	7½
1¼	.89	69	13.8	2.45	76	15.2	2.80	7
1⅛	.71	56	11.2	2.00	62	12.4	2.30	6
1	.60	45	9	1.58	50	10.0	1.80	5
⅞	.49	35	7	1.20	39	7.8	1.38	4½
¾	.375	26.3	5.26	.89	29	5.8	1.00	4
⅝	.28	19	3.8	.62	21	4.2	.72	3½
9/16	.25	14.5	2.9	.50	16	3.2	.58	3
½	.20¾	12.1	2.42	.39	13.3	2.7	.45	2¾

Type C — 5 Strands, 9 Wires to the Strand, One Hemp Core
Type D — 6 Strands, 8 Wires to the Strand, One Hemp Core

		Type C			Type D			
Diameter in Inches	List Price per Ft.	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Approx. Weight per Foot	Approx. Strength in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Approx. Weight per Foot	Diameter of Drum or Sheave in Feet Advised
1¼	$0.88	67	13.4	2.55	73	14.6	2.80	9¼
1⅛	.70	52	10.4	2.05	56	11.2	2.30	8
1	.58	42	8.4	1.65	46	9.2	1.80	6¾
⅞	.44	33	6.6	1.24	36	7.2	1.38	6
¾	.35	25	5.0	.92	27	5.4	1.00	5¼
⅝	.25	17½	3.5	.64	19	3.8	.72	4½
½	.16¼	11	2.2	.40	11.9	2.38	.45	3¾

Non-Spinning Hoisting Rope. Standard strengths adopted May 1, 1910. Eighteen strands, seven wires each, one hemp core.

Non-Spinning Rope is necessary in "back-haul" or single lin derricks, in shaft sinking and mine hoisting where the bucke or cage swings free. That of the best type is composed of si strands of seven wires each, laid around hemp core and co ered with an outer layer of twelve strands of seven wires eacl regular lay. It is made in Swedes iron, crucible cast steel, extr strong crucible cast steel, and plow steel. With a rope of thi type the Vermont Marble Co., of West Rutland, Vt., hoisted large block of marble, hanging free, 250 ft. without its making half turn. (Fig. 276.)

Extra Strong Crucible Cast Steel

List Price per Foot	Diameter in Inches	Approximate Circumference in Inches	Weight per Ft. in Pounds	Approximate Breaking Stress in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Recommended Diameter of Drum or Sheave in Feet
$1.10	1¾	5½	5.50	101.00	20.2	7.00
.94	1⅝	5	4.90	87.60	17.5	6.50
.80	1½	4¾	4.32	75.00	15.0	6.00
.68	1⅜	4¼	3.60	62.40	12.4	5.50
.56	1¼	4	2.80	51.60	10.3	5.00
.46	1⅛	3½	2.34	43.20	8.6	4.50
.37	1	3	1.73	33.00	6.6	4.00
.29	⅞	2¾	1.44	26.50	5.3	3.50
.22	¾	2¼	1.02	19.60	3.9	3.00
.16½	⅝	2	.70	13.10	2.6	2.50
.14	9/16	1¾	.57	10.70	2.1	2.25
.12½	½	1½	.42	8.10	1.6	2.00
.11½	7/16	1¼	.31	5.80	1.1	1.75
.11	⅜	1⅛	.25	4.60	.92	1.50

Plow Steel

List Price per Foot	Diameter in Inches	Approximate Circumference in Inches	Weight per Ft. in Pounds	Approximate Breaking Stress in Tons of 2,000 Lb.	Proper Working Load in Tons of 2,000 Lb.	Recommended Diameter of Drum or Sheave in Feet
$1.30	1¾	5½	5.50	111.10	22.2	7.00
1.08	1⅝	5	4.90	96.30	19.2	6.50
.93	1½	4¾	4.32	82.50	16.5	6.00
.79	1⅜	4¼	3.60	68.60	13.7	5.50
.65	1¼	4	2.80	56.80	11.3	5.00
.54	1⅛	3½	2.34	47.50	9.5	4.50
.43	1	3	1.73	36.30	7.2	4.00
.34	⅞	2¾	1.44	31.80	6.3	3.50
.26	¾	2¼	1.02	24.60	4.9	3.00
.19	⅝	2	.70	15.75	3.1	2.50
.16	9/16	1¾	.57	12.80	2.5	2.25
.14	½	1½	.42	9.75	1.9	2.00
.13	7/16	1¼	.31	6.85	1.3	1.75
.12½	⅜	1⅛	.25	5.55	1.1	1.50

Fig. 276.

Flat Wire Rope. Flat wire rope is composed of a number of wire ropes called flat rope strands of alternate right and left lay, usually of crucible steel placed side by side and sewed together with soft Swedish iron or steel wire. This sewing wire, being softer than the steel strands, acts as a cushion and wears out much faster than the strands themselves. The rope, however, is very easily repaired. As a large reel is not necessary for winding it, it is used principally where space is limited. It comes in widths of ½-in variation.

½ Inch Thick

Width and Thickness in Inches	Weight per Foot in Pounds	Approximate Breaking Stress* in Tons of 2,000 Pounds	Proper Working Load in Tons of 2,000 Pounds
½ x 7	5.90	89	13
½ x 6	5.10	77	11
½ x 5½	4.82	72	10.5
½ x 5	4,27	64	9.25
½ x 4½	4.00	60	8.50

Width and Thickness in Inches	Weight per Foot in Pounds	Approximate Breaking Stress* in Tons of 2,000 Pounds	Proper Working Load in Tons of 2,000 Pounds
½ x 4	3.30	50	7.25
½ x 3½	2.97	45	7.00
½ x 3	2.38	36	5.25
	⅜ INCH THICK		
⅜ x 5½	3.90	55	8
⅜ x 5	3.40	50	7.5
⅜ x 4½	3.12	47	7
⅜ x 4	2.86	43	6
⅜ x 3½	2.50	38	5.5
⅜ x 3	2.00	30	4.5
⅜ x 2½	1.86	28	4
⅜ x 2	1.19	18	2.5

* Crucible steel will average 30% to 50% stronger than the figures in these columns.

The approximate price per lb., crucible steel, is 21 cents.

Unless order distinctly specifies to the contrary, the rule for thickness applies to size of strand before sewing.

Wire rope is as flexible as new manila or hemp rope of the same strength, and when used as hauling, hoisting or standing rope is generally more durable. The working load for hoisting and haulage ropes should be about ⅕ the breaking strength; standing rope about ¼; in shafts and elevators from ⅐ to ⅒.

Use the largest drums and pulleys possible, and have them truly aligned with the rope. To increase the capacity of hoisting rope increase the load but not the speed, as the wear increases with the latter. Do not "fatigue" the rope unnecessarily by repeated shocks. A wire rope should be discarded by the time half the diameter of the outside wire is worn away.

Galvanized ropes have about 10% less strength than ungalvanized, and the latter may be protected from the weather by the use of one of the many oil, tar or grease mixtures.

In wire rope the outer fibres of each wire going round the sheaves are in tension, and the inner wires are in compression with a neutral point within the circumference of the rope. As the rope goes round the drum or sheave the result of these differential stresses is to produce a crawling or creeping or sliding of the wire upon each rope. It therefore follows that when thoroughly greased the life of wire rope will be very greatly increased. In *Engineering & Mining Journal* it is reported that the same kind of rope well oiled made 386,000 turns over 24-in. pulley before breaking, as against 75,000 turns when not oiled; a difference in favor of oiling of over 500%. In mine work when a rope is coated with cable compound once a week a steel wire

rope of best grade $1\frac{1}{2}$-in. in diameter with an ultimate strength of about 100 tons will last from 1 to $1\frac{1}{2}$ years. To prevent kinking, the cage should be lowered to the bottom of the shaft and the rope removed, being allowed to hang loose to uncoil.

In the Rookery Building, Chicago, 44 Swedish iron hoisting cables, $\frac{5}{8}$-in. diameter, of six strands of nineteen wires each, four cables to an elevator, have been running twelve years, without replacement. They are lubricated twice a year and carefully inspected each month. The hand rope in the same elevators, however, wears out very rapidly on account of the abrasion caused by the eye holes.

CABLE ON BROOKLYN BRIDGE

Cables in Order of Service	Term of Service Days	Distance Hauled	Passengers Hauled	Ton miles Hauled	Average Load, Tons	Average Rate of Live to Dead Loads
1	1,140	228,329	49,002,442	22,142,000	97	6
2	607	120,232	47,840,000	25,292,890	212	7.3
3	393	82,099	36,971,000	20,345,078	348.4	7.6
4	356	74,111	34,134,640	18,923,469	255.3	7.6
5	520	111,116	56,287,452	33,857,669	304.7	8.3
6	509	109,475	58,071,000	35,149,894	321.1	8.4

The life of street railway cable is likely to range from 60 to 115,000 miles where the cable itself is between 13,000 and 33,000 feet long. The average of 12 cables of which we have record is 74,017 miles.

A cable used on a Lidgerwood Unloader Plow on the Panama Canal work was installed April 12, 1909, and was first broken May 5, 1910. In the thirteen months it unloaded 1,830 nineteen-car trains of spoil from Culebra. This is a record, as the pull on these cables ranges from 90 to 125 tons. The life of the cable on this work averages from 350 to 500 trains. After breaking, the cables are spliced and used again.

The principal causes of destruction of wire ropes are:

(a) The wearing of the outer surface of the outside wires.

(b) The fatigue of the steel where the rope is worked over small pulleys.

As an example of the first case, the cable on cable tramways is worn by the grips; therefore, use a stiff cable with large wires; as an example of the second case, ropes used over small blocks break frequently; therefore, use a rope with small wires. The

strength of a wire rope is about 10% less than the sum of the strengths of the wires composing the rope.

A wire rope-way was constructed for the Plimosas Line consisting of an endless rope 20,230 feet long supported at intervals of from 104 to 1,935 feet on notch sheaves. "After the rope had been running about two years the splices commenced to give way at the points where the two cable strands are inserted into the rope to take the place of the hemp heart. * * * When new rope is spliced with old the new strands stand out somewhat more than the old ones and the wear is very rapid. * * * A flexible wire rope (19 wires to the strand) can be spliced so that there will be little difference in the wear; but, in a rope of seven-wire strands made out of plow steel, at the point just above and below where the two steel strands are inserted into the core and take the place of the hemp heart, there is a spot (about an inch in length) where the rope is seven strands instead of six on the circumference. This makes the diameter greater and increases the wear on the splice. * * * In a flexible rope the strands can be set together with a mallet so that the splice cannot be noticed."

Directions for Splicing Wire Rope.* Wire rope is susceptible to the most perfect splice; a smoother and better splice can be put in a wire rope than in any other kind of rope, for the simple reason that it is made with a view to this purpose. It has the desired number of strands and a hemp core which provides a place for fastening the ends. It is a plain, simple process, and but the work of an hour for any one to learn.

To Get the Length of the Rope to Be Spliced Endless. In most cases the ropes can be applied endless, and in such cases the ropes can be forwarded spliced ready to go on. Ropes ready spliced can be procured by giving the exact distance from center to center of shaft, and the exact diameters of the wheels on which the rope is to run. This measure can be got best by stretching a wire from shaft to shaft, marking the distance from center to center of shaft and carefully measuring the wire.

In cases where the endless rope cannot be put on, the rope has to be put around the sheaves, hove taut by pulley blocks, and the splice made on the spot. See Fig. 1 in diagram of splices.

The Necessary Tools. A hammer and sharp cold chisel for cutting the ends of strands; a steel point or marlin spike for opening strands; two slings of tarred rope with sticks for untwisting rope; a pocket knife for cutting the hemp core; a wooden mallet and block.

* Abstracted from catalogue of Broderick & Bascom Rope Co.

First. Put the rope around the sheaves, and heave it tight with block and fall. (See Fig. 1.) The blocks should be hitched far enough apart so as to give room between to make a 20-ft. splice. A small clamp may be used to prevent the lashing from slipping on the rope where the blocks are hitched. (See Fig. 1.) Next, see that the ropes overlap about 20 feet; about ten feet each way from the center, as shown by the arrow lines in Fig. 1. Next mark the center on both ropes with a piece of chalk, or by tying on a small string. Now proceed to put in the splice, with the blocks remaining taut when it is necessary; but the better way is to remove the blocks, throw off the rope from

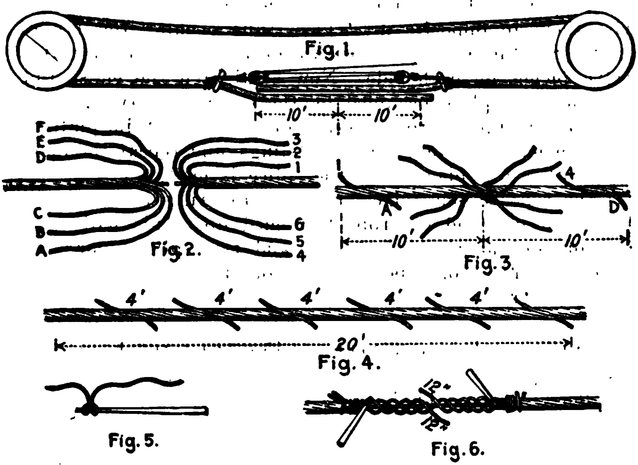


Fig. 277.

the sheaves, let it hang loose on the shafts, and proceed with the splice on the ground or floor, or scaffold, as the case may be.

Second. Unlay the strands of both ends of the rope for a distance of ten feet each, or to the center mark, as shown in Fig. 2. Next, cut off the hemp cores close up, as shown in Fig. 2, and bring the bunches of strands together so that the opposite strands will interlock regularly with each other. (See Fig. 3.)

Third. Unlay any strand, A, and follow up with strand 1 of the other end, laying it tightly in open groove made by unwinding A, make twist of the strand agree exactly with the twist of the open groove. Proceed with this until all but twelve inches

of 1 are laid in, or till A has become ten feet long. Next, cut off A, leaving an end about twelve inches long.

Fourth. Unlay a strand, 4, of the opposite end, and follow with strand D, laying it into the open groove as before, and treating this precisely as in the first case. (See Fig. 3.) Next, pursue the same course with B and 2, stopping four feet short of the first set. Next, with 5 and E, stopping as before; then with C and 3; and lastly with 6 and F. The strands are now all laid in with the ends four feet apart, as shown in Fig. 4.

Fifth and Last. The ends must now be secured without enlarging the diameter of the rope. Take two rope slings or twisters (see Fig. 5) and fasten them to the rope as shown in Fig. 6; twist them in opposite directions, thus opening the lay of the rope. (See Fig. 6.) Next, with a knife, cut the hemp core about twelve inches on each side. Now straighten the ends, and slip them into the place occupied by the core; then twist the slings back, closing up the rope, taking out any slight inequality with a wooden mallet. Next, shift the slings, and repeat the operation at the other five places, and the splice is made.

If the rope becomes slack, in time, and runs too loose, a piece can be cut out and the rope tightened up. This will require a piece of rope about 40 feet long and two splices, one splice to put on the piece of rope, and the other splice to join the two ends together.

Cost for Labor of Splicing Rope to Make Endless

Diameter of Rope in Inches	"List" for Splicing	Diameter of Rope in Inches	List for Splicing
¼ to 5/16	$2.50	⅞ to 1⅛	$4.00
⅜ to 7/16	3.00	1¼ to 1½	4.50
½ to ¾	3.50		

The above charge to be in addition to the extra rope used in making splice. These prices apply only on wire ropes spliced at the works of the manufacturer.

Manila and Sisal Rope. Manila and sisal rope are usually classed as "regular" rope or rope having three strands, four strand rope, bolt rope or especially selected long yarns and transmission rope which is of yarn selected and woven with great care. The prices are computed from a "base" which varies with the season and according to the condition of the trade.

The table below gives the standard sizes, weights, etc.

Sisal rope has approximately the same weight as Manila.

Manila about 25% stronger than sisal.

Hawser laid rope weighs about one-sixth less than 3 strand.

Manila Rope

Size in circumference	Size in diameter	Weight of 200 faths. Manila in lb.	Strain borne by new Manila rope	Length of Manila rope in one pound
6 th'd	¼ in.	22	620	55 ft.
9 th'd	5/16 in.	29	1,000	41 ft.
12 th'd	⅜ in.	44	1,275	27 ft.
15 th'd fine	⅜ in. full	50	1,600	24 ft.
15 th'd	7/16 in.	65	1,875	18 ft. 6 in.
1⅜ in.	7/16 in. full	75	2,100	16 ft. 0 in.
1½ in.	½ in.	90	2,400	13 ft. 4 in.
1¾ in.	9/16 in.	125	3,300	9 ft. 7 in.
2 in.	⅝ in.	160	4,000	7 ft. 6 in.
2¼ in.	¾ in.	198	4,700	6 ft. 1 in.
2½ in.	13/16 in.	234	5,600	5 ft. 1 in.
2¾ in.	⅞ in.	270	6,500	4 ft. 5 in.
3 in.	1 in.	324	7,500	3 ft. 8 in.
3¼ in.	1 1/16 in.	378	8,900	3 ft. 2 in.
3½ in.	1 ⅛ in.	432	10,500	2 ft. 9 in.
3¾ in.	1 ¼ in.	504	12,500	2 ft. 5 in.
4 in.	1 5/16 in.	576	14,000	2 ft. 1 in.
4¼ in.	1 ⅜ in.	648	15,400	1 ft. 10 in.
4½ in.	1 ½ in.	720	17,000	1 ft. 8 in.
4¾ in.	1 9/16 in.	810	18,400	1 ft. 6 in.
5 in.	1 ⅝ in.	900	20,000	1 ft. 4 in.
5½ in.	1 ¾ in.	1,080	25,000	1 ft. 1 in.
6 in.	2 in.	1,296	30,000	11 in.
6½ in.	2 ⅛ in.	1,512	33,000	9½ in.
7 in.	2 ¼ in.	1,764	37,000	8 in.
7½ in.	2 ½ in.	2,016	43,000	7 in.
8 in.	2 ⅝ in.	2,304	50,000	6¼ in.
8½ in.	2 ⅞ in.	2,590	56.000	5½ in.
9 in.	3 in.	2,915	62,000	5 in.
9½ in.	3 ⅛ in.	3,240	68,000	4½ in.
10 in.	3 ¼ in.	3,600	75,000	4 in.

Manila Transmission Rope

Diameter inches	Approximate weight in lb. per 100 ft.	Approximate breaking strength	Length in ft. required for splice	Smallest diam. of sheave
¾	20	4,500	8	28
⅞	26	6,125	8	32
1	34	8,000	10	36
1⅛	43	10,125	10	40
1¼	53	12,500	10	46
1⅜	65	15,125	12	50
1½	77	18,000	12	54
1⅝	90	21,125	12	60
1¾	104	24,500	12	64
2	136	32,000	14	72

Mr. George J. Bishop in 1897 made some records to determine the life of manila rope in pile driving. The drum of the engine and the sheave on the top of the leads were 14 in. in diameter. The sheave at the front of the pile driver was 10 in. The hammer weighed 10,000 lb. The rope was of three different makes of 1½-in diameter. Common manila three-ply rope made the best show-

Tensile Strength of Different Kinds of Wire Rope, Compared with Manila Rope

Approximate Breaking Stress Calculated in Tons of 2,000 Pounds

	Wire Transmission Rope. One Hemp Core Surrounded by Six Strands of Seven Wires Each				Wire Hoisting Rope. One Hemp Core Surrounded by Six Strands of Nineteen Wires Each				
Diameter in inches	Iron tons	Crucible cast steel tons	Extra strong crucible cast steel tons	Plow steel tons	Iron tons	Crucible cast steel tons	Extra strong crucible cast steel tons	Plow steel tons	Average quality new Manila rope tons
2¾	...	...	....	...	111	211	243	275	26
2⅝	...	...	....	...	92	170	200	229	21
2¼	...	...	....	...	72	133	160	186	17
2	...	...	....	...	55	106	123	140	13½
1¾	...	...	....	...	44	85	99	112	11
1⅝	...	...	....	...	38	72	83	94	9½
1½	32	63	73	82	33	64	73	82	8
1⅜	28	53	63	72	28	56	64	72	7
1¼	23	46	54	60	22.8	47	53	58	6
1⅛	19	37	43	47	18.6	38	43	47	5
1	15	31	35	38	14.5	30	34	38	4
⅞	12	24	28	31	11.8	23	26	29	3
¾	8.8	18.6	21	23	8.5	17.5	20.2	23	2¼
⅝	6	13	14.5	16	6	12.5	14	15.5	1½
9/16	4.8	10	11	12	4.7	10	11.2	12.3	1¼
½	3.7	7.7	8.85	10	3.9	8.4	9.2	10	1
7/16	2.6	5.5	6.25	7	2.9	6.5	7.25	8	¾
⅜	2.2	4.6	5.25	5.9	2.4	4.8	5.30	5.75	½
5/16	1.7	3.5	3.95	4.4	1.5	3.1	3.50	3.8	⅜
9/32	1.2	2.5	2.95	3.4	..	..	...	...	3/10
¼	...	...	....	...	1.1	2.2	2.43	2.65	¼

ing. The length of rope was 125 ft., and its weight ranged from 74 to 95 lb.; average 85 lb., or nearly 0.7 lb. per foot. The price of the rope was 6½ cents per lb., or $5.53 per average rope. Ten ropes were used up in driving 1,335 piles to an average penetration of 20 ft.; hence, each rope averaged 135 piles at a cost of 4 cents per pile per rope. However, 5 ropes averaged only 101 piles each, and 5 averaged 166 piles each.

The Plymouth Cordage Company in 1910–11 conducted a series of tests on various brands of rope to determine the extent to

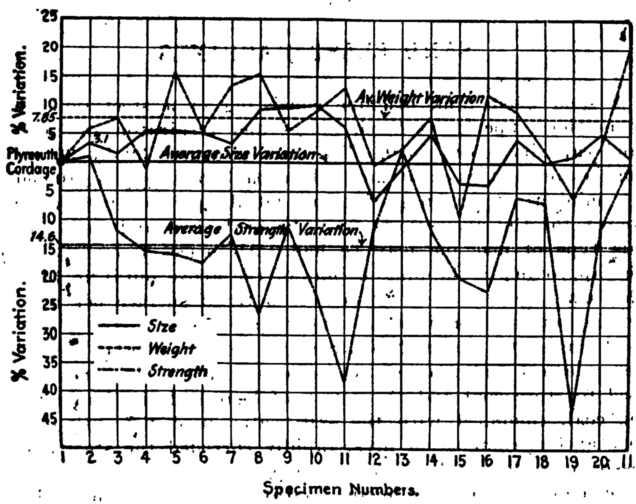


Fig. 278. Diagram Showing Variation of Wire Rope from Standard Plymouth Cordage.

which manila rope might vary in quality. An average Plymouth cordage sample was used as a standard and from this the variations plus or minus, in size, weight and strength were plotted on the accompanying diagram. Twenty-two samples of rope nominally 3 in. in circumference, made by various manufacturers, were tested. The strongest rope failed under a load of 9,010 lb., while the weakest was able to stand only 4,946 lb. Glancing at the table it will be seen that in several cases where the size curve shows a decided rise the weight curve dips. It would be natural to suppose that the weight would increase correspond-

ingly with the size, but this does not seem to be the case and must indicate that some brands are more loosely twisted than others. As will be noticed the weights vary between minus 9.61% and plus 20% and the table shows that so-called 3-in. rope is not always 3 in. in circumference.

SECTION 82

SAND BLAST MACHINES

A sand blast tank machine consisting of a steel tank, hose, connections, operator's hood, gloves and respirator, of 1,000 lb. sand capacity, costs $310. The tank measures 30 by 30 in. A compressor for this outfit should be capable of supplying 100 cu. ft. per min. at a pressure of about 60 lb. per sq. in. A screen hopper for the above costs $85. Several sizes and capacities in this type of machine may be had. All prices f. o. b. Chicago. The approximate shipping weight of the above outfit is 1,000 lb. This machine will clean from 2 to 3 ft. of surface per min. depending on the condition of the surface.

At the United States Naval Station, Key West, Fla., steel sheds were cleaned and painted by compressed air. These sheds were used to store coal and the action of heat and the impurities in the coal, combined with the salt water used for extinguishing spontaneous combustion fires, rapidly corroded the steel and necessitated a thorough cleaning and painting every time the sheds were emptied. The following outfit was purchased and cost $2,090:

1 horizontal gasoline engine, about 20 hp.
1 air compressor, capacity about 90 ft. of free air per min. compressed to a pressure of 30 lb. per sq. in. in one stage, belt connected to engine.
1 rotary circulating pump, belt connected to engine.
1 galvanized steel water tank.
1 air receiver, 18 x 54 in.
(The above apparatus was all mounted on steel frame wagon with wooden housing.)
2 sand blast machines, capacity 2 cu. ft. of sand each.
2 paint spraying machines, one a hand machine of ⅔ gal. capacity for one operator, the other of 10 gal. capacity for two operators.
100 lin. ft. of sand blast hose.
200 lin. ft. of pneumatic hose for sand blast machines.
400 lin. ft. of pneumatic hose for painting machines.
100 lin. ft. of air and paint hose for painting machines.
4 khaki helmets, with mica-covered openings for the eyes.
200 lin. ft. of 2-in. galvanized iron pipe.

Cleaning by hand cost over 4 cents per square ft. in 1910. The labor cost per day of cleaning by machine is shown in the following:

1 engine tender	$ 3,04
1 helper (in charge of the work and tending machines)	2.24
2 laborers on machines at $1.76 each	3.52
1 laborer drying sand, filling machines, etc.	1.76
Total (1910 figures)	$10.56

9,000 square feet of surface were cleaned at a cost for labor of $97.68 and for gasoline of $16.15, or at the rate of less than 1½ cents per square foot; 9,000 square feet of surface were painted at a cost for labor of $28.16 and for gasoline of $3.80, or at the rate of ⅖ cent per square foot (1910). The interest, depreciation and repairs to plant would add an inconsiderable amount to this.

SECTION 83

SAND AND GRAVEL WASHERS

A portable Sand and Gravel Washing Machine, rated by the manufacturer at 10 to 12 yd. per hr., costs $2,750 f. o. b. Chicago. This machine is equipped with a gasoline engine and is mounted on wheels. In operation the elevator carries the material from the ground level, spouting it into a preliminary scrubber from which it goes into a conical screen which removes the oversize, producing one grade of gravel and one of sand. The oversize, gravel and sand, are spouted from the machine in separate chutes.

A Patented Sand and Gravel Washer consisting of a hopper into which is put the material to be screened, and the water for washing, a screen made up of several conical, nested screens, and suitable arrangement for driving, but not with power equipment, costs as follows:

Capacity in cu. yd. per hr.	Approximate weight in lb.	Price f. o. b. Minnesota
20 to 30	2100	$ 800
40 to 50	2700	1,000
50 to 60	3700	1,200

SECTION 84

SAWS

Saw Tables. A belt driven circular saw, of a simple type, tha will cut timber up to 10 inches weighs 300 lb. for shipment an costs $30. A similar saw with an extended table that will swin a saw up to 30 in. in diameter weighs 330 lb. and costs $32. Another rig with countershaft weighs 335 lb. and costs $37.

These saws are primarily designed to cut up wood for fuel, but may also be used for more exacting work within certain limits.

Portable Combination Swing Cut Off and Ripping Saws. An outfit consisting of a complete adjustable table, with cross cut gauge and saw guard, ripping gauge, mitre gauge, saw dust guard,

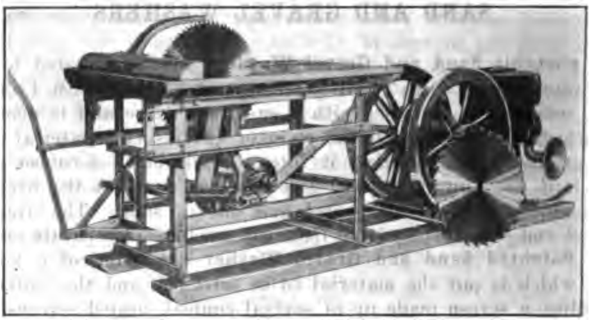


Fig. 279. Combination Swing Cut-Off and Ripping Machine.

complete idler with lever and brake, swing frame with idler, leather belt for swing frame, 14 inch rip saw, 16 in. cross cut saw, all mounted on yellow pine skids, costs $265 without engine and engine belt. Complete outfit with 5 hp. gasoline or kerosene engine, $400.

An outfit similar to the above with 16-in. rip saw and 20-in. cross cut saw without engine costs $300. With 7 hp. engine, $500.

An outfit similar to the two above with 34-in. rip saw and 34-in.

ross cut saw costs without engine $450. With 9 hp. engine complete, $750.

Extras for the above

9 in. diameter dado	$ 8.50
8 in. emery wheel	2.25
12 in. rip saw	6.25
12 in. cross cut	6.25
14 in. rip saw	7.50
14 in. cross cut	7.50
16 in. rip saw	9.50
16 in. cross cut	9.50
34 in. rip saw	33.75
34 in. cross cut	33.75

A Universal Tool Unit to attach to any of the above machines is composed of a 6 in. jointer and guard, adjustable jointer beds, adjustable jointer gauge, boring machine with ½, ¾ and 1-inch

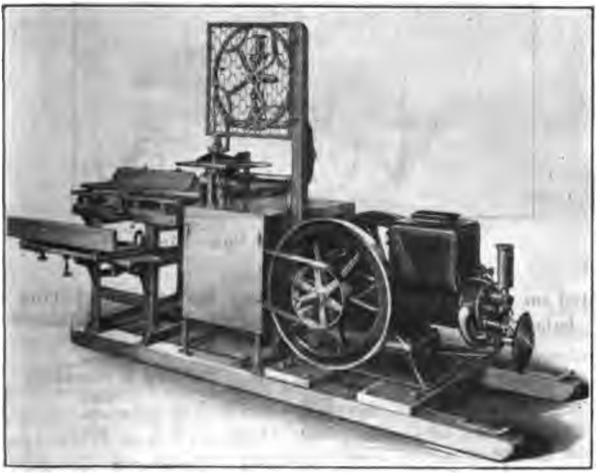


Fig. 280. Portable Woodworker.

bits and complete adjustable sliding boring and sanding table, 10 in. sander, mandrel, and iron frame ready to attach to the swing frame. Price complete $114.

A Portable Woodworker similar to the one shown in Fig. 280 costs as follows:

1 — 12 inch rip saw	$ 6.25
1 — 14 inch cross cut saw	7.50
1 — 8 inch diameter dado for grooving and rabbetting, widths 3/16 to 1¾ in., depths up to 1¾ in.	8.75

1 — 6 inch jointer complete	70.00
1 — Boring attachment complete	20.00
1 — 8 inch emery wheel	2.25
1 — 10 inch sander	4.00
1 — Wood saw table with ripping gauge, combination mitre and cross cut gauge saw mandrel with pulley, belt tightener with saw guard	106.25
1 — 3 hp. engine with magneto and belt	110.00
Woodworker complete with all attachments	335.00
Woodworker with 12 in. rip saw, 14 in. cross cut saw, table and gauges, 3 hp. engine (no attachments)	230.00
22-inch band saw attachment complete with one saw	70.00
Countershaft and pulleys for electric motor	20.00
5-hp. engine, extra	65.00

Portable Saw Rigs similar to the one shown in Fig 281 are made in several types. A rig designed for sawing pole or cord wood consisting of an engine complete with battery ignition,

Fig. 281. Portable Saw Rig.

mounted on a long truck with seat tool box, tongue, tilting saw table, balance wheel, belt tightener and saw costs as follows:

Hp. of engine	Approximate shipping weight in lb.	Price f. o. b. Wisconsin
5	2000	$345
7	2350	425
9	2850	550

A patented rig similar to the above, arranged so that the saw attachment can be removed so that the engine can be used as a portable costs as follows:

Hp. of engine	Approximate shipping weight in lb.	Price f. o. b. Wisconsin
5	2000	$365
7	2350	445
9	2900	570
12	3500	740

Portable Saw Mill similar to the one shown in Fig. 282 has an average capacity of about 4,000 ft. per day when operated with a

horse power of from 15 to 20. Wide variation from this figure is possible depending on the kind of wood cut and the experience of the crew.

A mill with a carriage 16 ft. by 26 in., having a variable friction feed with a length of track and ways of 40 ft., weighs complete 2,800 lb., and costs $404. The standard saw for this machine is 48 in. in diameter at a cost of $108 extra.

Another saw mill with a patented feed will swing a 52-in. saw. It has a carriage 20 ft. by 36 in., length of track 56 ft. It weighs complete 5,550 lb. and costs $743. 52-in. saw, $141.

A saw mill having a 20 ft. by 40 in. carriage and a 56 ft. track weighs 7,500 lb., and costs $1,170. Saw same as before.

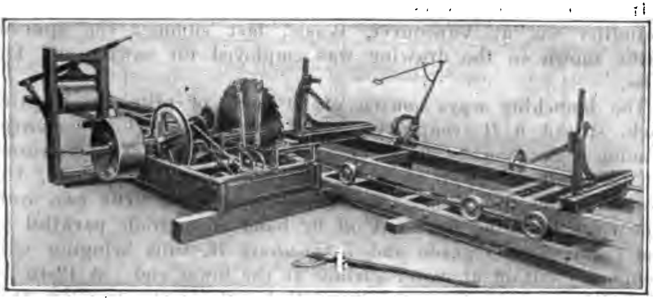


Fig. 282. Saw Mill.

Outfits for Cutting off Piles Below Water Line. An effective arrangement for sawing off piles under water is employed by Whitney Bros. Co., general marine contractors, Superior, Wis. Their equipment consists of a machine very similar in appearance to a small swing pile driver. Instead of the drop hammer in the leads, there is a 3-in. shaft, which is raised and lowered by the usual hoisting cables. The shaft runs through boxes, which are attached to guides which run up and down the leads according to the depth required. A 12-in. belt drives the shaft which runs from a drum on the hoisting engine. This engine also furnishes power for turning the leads to the position required. A 48-in. circular saw is attached to the bottom of the shaft. The whole equipment is usually mounted on a flat scow, at each end of which is placed a steam winch which furnishes the motive power.

The procedure, for instance on an ore dock foundation, is to start with the leads swung in line with the center of the first row of piling and then proceed the length of the row with the

use of the steam winches. The machine is then swung around and the second row is cut off by the same method. Each row in turn is sawed off, it being only necessary to swing the driver the distance required to be in line of the center of each succeeding row.

It has been found that this equipment makes a very accurate cut at depths down as far as 28 ft. The average capacity is approximately 500 piles per 10-hour day. However, on several occasions an average run of 960 piles and over per day has been kept up for two weeks running. The cost of cutting the piles varies, of courses, with labor and material conditions. It ranges around 15 ct. to 50 ct. per pile according to depth.

In extending the ways at the steel ship yards of the G. M. Standifer Co. at Vancouver, Wash., last summer the special outfit shown in the drawing was employed for sawing off the piles.

The launching ways consist of 39 bents of piling of 8 piles each, spread 6 ft. center to center of bents. All underwater bracing was done by divers before starting cut-off operations. At the stage of river at which the work was to be done, the lowest cut-off was some 7 ft. below water level. The two outside rows of piling were cut off by hand on a grade parallel to the required true grade and 7 ft. above it, thus bringing this temporary cut-off at water surface at the lower end. A 12-in × 12-in. cap was then placed the full length of the way on this temporary cut-off. This cap was fitted with a 3-in. × 4-in. strip on top to act as a guide on which the carriage support was to move. The remaining inner rows of piling were not cut.

The carriage support consisted of two 10-in. × 12-in. timbers, cross braced 8 ft. apart and fitted with truss rods so as to span the space between the two temporary caps. On these two timbers were fitted 2-in. × 2-in. strips with a 2-in. × 2-in. angle iron to serve as a rail for the traveling carriage. On the carriage was mounted a 25-hp. motor which drove the saw shaft with a quarter-turn belt. The saw shaft was set square with the carriage framing and so varied from the vertical an amount equal to the grade angle.

The 48-in. circular saw was fitted at the lower end of this shaft at the elevation of 7 ft. below the temporary cut-off — that is, so it would cut on the true grade line. A hand windlass with light cable anchored at the ends of the carriage support provided means for movement of the carriage transversely. The carriage support was pulled ahead from bent to bent by cable line from a donkey engine on shore.

In operating the saw the carriage was moved to the upper end

of the way with the saw on the lower side. The donkey line skidded it ahead along the temporary caps to the first bent. The saw was started in the center space and cut the piling on one side of the center line, being fed through them by the hand windlass. The outside pile was only cut about three-fourths through on account of its supporting the saw. The saw was then fed through the piling at the opposite side of the center line, and returned to the center ready to be skidded ahead to the next bent. The outside piles were cut the remaining amount by hand

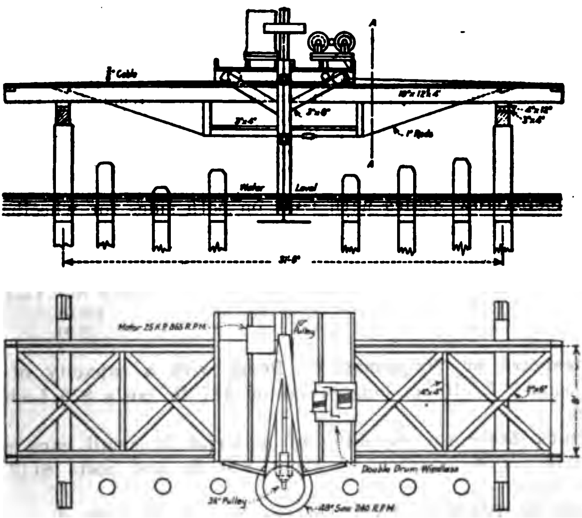


Fig. 283. Cut-off Saw for Cutting off Piles below Water Line.

after the saw had passed over. Caps were placed in the usual way by divers using block and tackle. The full equipment was easily transferred to the next way.

A distinct advantage of the saw cutting was that it preserved a very true and even grade in spite of the small irregularities in the driving of piles. The time actually required for cutting off one way after the preliminary work was done, was about 2½ or 3 hours, one way of 216 piles actually being done in 1 hr. and 50 min.

SECTION 85

SCALES

Portable Platform Scales adapted to the weighing of all kinds of general merchandise.

Capacity in lb.	Size of platform in inches	Price f. o. b. New York
500	16 by 25	$24.00
1000	18 by 27	31.20
1500	22 by 31	44.80
2500	25 by 34	68.00

Wheelbarrow Scales with runs on both sides for wheelbarrows and hand trucks.

Capacity in lb.	Size of platform in inches	Price f. o. b. New York
1000	42 by 30	$76.00
2000	44 by 35	96.00

Steelyard or Weighmaster's Beam with a capacity of 2,000 lb. beam 7 ft. 10 in. long, weighing 127 lb. costs $76 f.o.b. New York.

Track Scale for weighing of material in small cars with a capacity of 4 tons weighs about 820 lb. and costs $112 f.o.b. New York.

Cost of Track Scales.* On the New York Central a 100-ton track scale, 42 ft. long, cost as follows, in 1902:

Scales and materials	$1,760.00
Labor	640.00
Total	$2,400.00
8.7 tons rails (relayers), at $20	$ 174.00
15 ties at $0.60	9.00
Miscellaneous material	150.00
Labor laying track, etc.	70.00
Grand total	$2,803.00

No piles were used in foundation.

The cost of 50-ton track scales, 42 ft. long, on the Northern Pacific, in 1899, averaged as follows:

* Hand Book of Cost Data, by H. P. Gillette.

Scales, delivered	$ 580.00
Other materials	170.00
Labor ($175 to $300)	250.00
Total	$1,000.00

The cost of 80-ton track scales, 50 ft. long, in 1905, was as follows:

Scales and materials	$1,250.00
Labor ($500 to $700)	650.00
Total	$1,900.00

SECTION 86

SCARIFIERS

A scarifier illustrated by Fig. 284 is so designed that it ma be steered independently of the hauling engine and can tur around in its own tracks. The teeth can be lowered or lifte instantly by a lever and the angle at which they enter th ground can be adjusted to suit conditions. It may be haule by a road roller of 10 tons or more and two men, one on th roller and one guiding the scarifier constitute the crew. Thi machine costs $700 f.o.b. Chicago.

Fig. 284. Scarifier.

A pneumatic scarifier for attachment to a motor road roller consists of a cylinder attached to the rear of the roller frame and is operated by air pressure from the storage tanks. The teeth are forced downward by the air pressure on the piston. The air is supplied by a small compressor mounted on the engine cylinder and operated by the engine from the crank shaft. This attachment costs $1,100 f.o.b. Chicago. A similar attachment for a steam roller operated by steam costs $700.

A scarifier for attachment to a steam roller weighs 1,150 lb. and costs $450.

Another type of scarifier, built on the same general lines as a

road machine, and also fitted with a grader blade, has 5 rooter teeth on 10 inch centers, the width of the blade is 9 ft., the weight is approximately 8,400 lb.; price $1,500 f. o. b. Chicago.

The following is the cost of ripping up pavement by hand compared with the cost of doing this by machine.

20 men with picks at $2.00 per day	$ 40.00
Sharpening 80 picks at 10 ct.	8.00
Foreman	3.00
Cost per day for 170 ft. of road 16 ft. wide	$ 51.00
Cost per mile	$1,585.00

The cost by machine was as follows:

Operator on machine	$ 2.50
Sharpening picks	2.50
Roller operator	3.00
Fuel, etc.	2.00
Rent of roller	10.00
Cost per day for 1818 ft. of road 16 ft. wide	$20.00
Cost per mile	$57.00

SECTION 87

SCRAPERS

(See Grading Machines, page 388)

SECTION 88

SCREENS

(See Crushers.)

Ordinary sand and coal screens cost from $6 to $18 each.

A make of revolving screen mounted on a wooden frame and furnished with shafting, gears, etc., but no power, is made in two standard diameters. Any practical length or number of sizing sections may be had. The following are the prices of two sizes:

Diameter in inches	Length in feet	Approximate weight in lb.	Price f. o. b. Chicago
24	10	1800	$308
32	12	5000	660

Screens in permanent plants should be made of the best steel. A carbon steel screen of $\frac{3}{8}$-in. plate, after handling 10,000 to

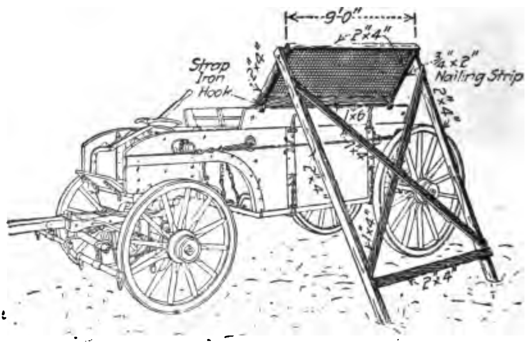


Fig. 285. Wagon Side Screen.

14,000 yards of crushed trap rock, was reduced to $\frac{1}{8}$ inch at the point where the chute delivered it. The holes had been enlarged from $1\frac{3}{16}$ inches to $1\frac{13}{16}$ inches, and from $2\frac{1}{4}$ inches to $2\frac{7}{8}$ inches. A $\frac{1}{2}$-inch rolled manganese steel plate screen replaced

the first screen, and after handling 10,000 cubic yards showed no appreciable wear.

Another make of screens mounted on frames with no power costs as follows:

Diameter in inches	Length in feet	Prices f. o. b. factory
24 Gear driven	8	$ 192
30 Gear driven	8	240
36 Gear driven	10	328
42 Gear driven	16	597
51 Roller driven	20	1,850
60 Roller driven	24	2,800

The above screens may be had in other lengths than those indicated at corresponding prices.

Wagon Side Screen. A screen illustrated by Fig. 285 was described in *Engineering News-Record* by Donald A. Thomas.

The screen is supported by props and by one side of the wagon being loaded. Using the ordinary mason's screen, the cost of this work averaged about 44 ct. per yd. for the screened product, including loading. About one-third of the material handled was waste. By throwing the material against the wagon screen, allowing the waste to drop to the ground and the screened gravel to roll into the wagon, the cost given was cut to about 22 ct. per yard.

The screen used was 3 ft. wide, and the length of the dump wagon about 9 ft. The frame is made of 2 x 4-in. scantling with two cross-braces of the same material. It is covered with screen wire having ¼-in. to ⅓-in. mesh, which gives a satisfactory product. The angle at which the screen is set can be varied to suit the material being dug. The lower edge of the screen is provided with hooks to hang on the side boards of the wagon, while the other side of the screen is supported by posts hinged on bolts to the edge of the frame.

SECTION 89

SHOVELS

There is not much difference in cost between a poor shovel and a good one and this difference is quickly made up, with the use of a good shovel, in the added life and the increase in the material handled over that of the poor type. For each particular kind of work there is a shovel designed which is best suited to produce the most work with a given effort. In excavating a long handled shovel is generally to be preferred and it should be of a type having the handle nearly parallel to the blade. For loose material a square pointed shovel is better than a round pointed one, as more material can be handled with it than with the round, using practically the same effort.

In unloading material from a steel car a pointed end shovel is best to start the work. After the bottom of the car has been reached the square pointed shovel is the best to use. This type of shovel should have a bend near the blade so that the shovel can be gripped close to the load, which will add to the ease of shoveling.

In mixing concrete on a platform a square pointed shovel is to be preferred. A shovel for this purpose should have a low rib so that the material will not stick to the blade.

A shovel for packing the concrete in forms should not have much rib that may become clogged. A perforated shovel is good for this use but it should be carefully cleaned as the concrete will harden and fill up the perforations. If it hardens, the shovel is liable to break when hit to dislodge the concrete.

Concrete Facing Spades with long handles and perforated blades cost about $22.80 per doz. with handles 4½ ft. long.

Concrete Shovels with hollow back and square point, D handles, cost $24.70 per doz.

Ore Shovels with hollow back and D handle cost $24.70 per doz.

Back Strap and Hollow Back round and square point shovels cost from $22.80 to $24.40 per doz.

Back Strap and Hollow Back Scoops cost from $24.70 to $27.10 per doz.

Breakdown Scoops cost from $28.50 to $30.90 per doz.

Telegraph Post Hole Shovels cost about $24 per doz. with 8-ft. handles.

Telegraph Post Hole Spoons with 8-ft. handles cost about $24 per dozen.

A Study of Shoveling as Applied to Mining. The following notes from a paper by G. Townsend Harley in the *Bulletin of the American Institute of Mining Engineers* are quoted here with keen admiration for their scientific value and scholarly presentation:

Stoping methods in which shoveling plays an important part are gradually being replaced by other and cheaper methods. But there will always be considerable shoveling done underground in stopes as well as in drifts, tunnels, winzes, and shafts. At the mines of the Phelps-Dodge Corporation at Tyrone, N. M., the cost of shoveling in all stopes in 1917 amounted to 24 ct. per T. In the top-slice stopes for the same period, it cost 27 ct. per T. or 16% of the total cost of these stopes. The tonnage for shovelers from all stoping was 9.3 T. per man, and for top-slicing 8.2 T. per man. These stopes were not unduly hot, and there was not more than the usual amount of timber to interfere with the work of the men.

The tonnages obtained per shoveler were considered low; first, because of a poor grade of Mexican labor, many of the men having come in from railroad grading camps; and second, because of a poor spacing of raises, especially in the top-slice stopes, where, in general, they were spaced 25 ft. by 66 ft. centers. The average wage per laborer shift was $2 67 during the year. It was thought, however, that even under these conditions the men were not producing the tonnage that they should, and with the consent of the management, the writer undertook to determine how the general efficiency of the underground shoveling could be improved.

Preliminary Work. As a first step, several weeks were spent underground making a general survey of the field and making time studies on various men, in order to see what points would need to be determined for a full consideration of the subject. The following factors were soon recognized:

1. The type, weight, size, and design of shovel giving the greatest shift tonnage without too much wear and tear on the man would have to be determined. This work would also determine the point at which a shovel should be discarded as worn out.

2. A standard of comparison would be necessary if the ill effects of mine air, powder gas and smoke, temperature, humidity, and poor light were to be estimated.

3. The layout and spacing of chutes would have to be studied with regard to their effect on shoveling directly into the chutes, or loading into wheelbarrows or cars and tramming to them. This work would determine the proper distance at which shoveling into a chute should leave off and loading into a wheelbarrow or car be taken up. The information would also be of very great use in planning the development of a stope.

TABLE 1.—WEIGHTS AND VOLUME OF BROKEN ORE

Cubic Feet of Broken Ore per Ton	Pounds of Ore in 1 Cu. Ft.	Pound of Ore in 1 Cu. In.	Cubic Inches of Ore in a 21-lb. Load	Cubic Feet of Broken Ore per Ton	Pounds of Ore in 1 Cu. Ft.	Pound of Ore in 1 Cu. In.	Cubic Inches of Ore in a 21-lb. Load
10	200	0.1157	182	26	77	0.0446	471
11	182	0.1503	199	27	74	0.0428	491
12	167	0.0966	217	28	71	0.0411	511
13	154	0.0891	236	29	69	0.0399	526
14	143	0.0828	254	30	67	0.0388	541
15	133	0.0769	273	31	65	0.0376	558
16	125	0.0723	290	32	63	0.0365	575
17	118	0.0683	307	33	61	0.0353	595
18	111	0.0642	327	34	59	0.0341	616
19	105	0.0608	345	35	57	0.0329	638
*20	100	0.0579	363	36	56	0.0324	648
21	95	0.0549	383	37	54	0.0313	671
22	91	0.0527	398	38	53	0.0307	684
23	87	0.0504	417	39	51	0.0295	712
24	83	0.0480	438	40	50	0.0289	727
25	80	0.0463	454				

* This was the ore handled in these tests.

4. Hindrances to work such as timber standing in line of throw or very closely spaced, men and supplies passing back and forth through working space, etc.

5. Manner of placing the shovelers to obtain maximum results from them, number of men in one working place, and size of working place required per man.

6. The hours of actual work and the cause and amount of delays, such as shoveler interrupted to help in other work, etc.

7. The capacity of a man for work as the day progresses.

8. Proper rest periods for men to maintain maximum efficiency.

9. Best means for instructing men and supervision work.

At the time this work was started, three types of shovels were in general use at the mines; a No. 2 scoop, used principally by contractors in development work, but favored by some of the shift bosses for use in the stopes; a No. 2 or a No. 3 square-point

TABLE 2.—CAPACITY IN CUBIC INCHES OF VARIOUS TYPES AND SIZES OF SHOVELS.

Capacity in Cubic Inches	Size of Shovel Blade, In. Width	Length	Square Point, Plain or Back Strap Number	Round Point, Plain or Back Strap Number	Scoop, Plain or Back Strap Number	Scoop Hollow Back Number
249	9⅞	11⅞	....	2		
278	10¼	12½	....	3		
302	9⅞	11⅞	2			
308	10⅞	12¾	....	4		
340	10¼	12½	3			
340	11⅜	13¼	....	5		
363	10	13	*			
373	10⅞	12¾	4			
384	11¾	13¾	....	6		
414	11⅜	13¼	5			
446	11¾	13¾	6			
457	11¼	15	....	....	2 E.P.	2 E.P.
521	11½	15½	....	....	3 E.P.	3 E.P.
564	11¾	16	....	....	4 E.P.	4 E.P.
579	12¾	15½	....	....	1 W.P.	4 W.P.
622	12⅝	16½	....	....	5 E.P.	5 E.P.
633	13	16¼	....	....	2 W.P.	5 W.P.
665	12⅞	16¾	....	....	6 E.P.	6 E.P.
706	13⅜	17	....	....	7 E.P.	7 E.P.
721	13¾	17	....	....	3 W.P.	6 W.P.
761	13¾	17½	....	....	8 E.P.	8 E.P.
802	14¼	17¾	....	....	4 W.P.	7 W.P.
832	14⅛	18	....	....	9 E.P.	9 E.P.
881	14⅝	18½	....	....	5 W.P.	8 W.P.
910	15⅛	18½	....	....	10 E.P.	10 E.P.
934	14⅞	19	....	....	6 W.P.	9 W.P.
1042	15¾	19¾	....	....	12 E.P.	12 E.P.

* Specially Made Test Shovel.
E.P. = Eastern Pattern Scoop.
W.P. = Western Pattern Scoop.

D-handle shovel for shoveling off of a mat in the stopes; and a No. 2 round-point long-handle shovel, for scraping down a muck pile, shoveling off of a rough bottom, cleaning up, etc. The first task was to determine the average load that the various types and sizes of shovels would handle, in order to be able to determine whether the 21-lb. load, as advocated by Dr. Taylor, applied to underground work as well as to the surface work, and whether it was the best load for the average Mexican laborer of the Southwest. These average capacities were obtained by repeatedly shoveling a weighed pile of ore with each of the shovels and counting the number of shovel loads required to move it. Table 1 gives the number of cubic inches of ore in a 21-lb load, for ore breaking to different volumes per ton; and Table 2 gives the sizes and types of shovels that will average

up to any given content. Owing to the variety of conditions in underground shoveling, such as the material of which the shoveling platform is made, whether of wood, iron, or natural bottom; the unsized material shoveled; and the amount of moisture in the ore, causing it to be sticky at times; these average shovel capacities were found not to accord with actual practice, except over test periods of long duration; for short periods they would vary as much as ¾ lb. from the average, while single shovel loads would vary as much as 3 lb. For Burro Mountain ore, the tables show that it requires a specially made shovel with a 10- by 13-in. blade to hold the 21-lb. load, or 363 cu. in. In practice, however, we are using at the present time a No. 4 square-point shovel holding 373 cu. in. and a No. 5 round-point shovel holding 340 cu. in.

During the period of preliminary work, it was discovered that the work of a shoveler can be classified into the following divisions, each susceptible to comprehensive study and analysis, and to each of which can be given a definite relative time value.

Time spent actually shoveling, which may be divided into: Penetrating mass, lifting mass, throwing mass, and return to start of first motion.

Time spent picking down, considered as a rest.

Tramming and dumping time, with wheelbarrow or car.

Time spent resting, divided into: Definite rest periods and delays due to interferences, blasting, men and supplies passing, etc.

Time spent other than in shoveling, not counted in shoveling time, but included delays before starting to work, lunch period, quitting early at end of shift, and time spent on other work, helping machine man, timbermen, etc.

By studying each motion separately, it was possible to establish a standard time for each and, consequently, a standard of performance for the whole. It was possible, also, to discover which were the most tiring motions and how each was affected by length of time worked, length and distribution of rest periods, size of shovel, design of shovel, and length of throw.

It was, of course, impossible to time all the motions made with any one shovelful; consequently these figures had to be obtained in rotation, each figure set down on the sheet being an average of 10 consecutive readings. All delays and rest periods were timed and all wheelbarrow and car loads counted. As a check on the tonnage handled, a record was made of the number of shovelfuls making up a load, the average capacity of the shovel and of the wheelbarrow or car, an estimate was made of the tonnage in the original pile and, in many cases, the tonnage drawn

out of the chute into which the man was shoveling or dumping the ore.

Investigations Made on Surface. In order to obtain some standard of comparison for the underground work, some of the mine shovelers were brought to the surface and a record made of their work under ideal conditions; that is, with good air, good light, no timber to interfere, steady shoveling for various lengths of time, and standard lengths of throw for the muck. A platform was built on the side of the mine-waste dump, about 12 ft. below the yard level, with a slide from the track above so arranged that no matter what quantity of muck was in the slide the toe of the pile was always in the same place on the platform and the shoveler did not have to move up as shoveling progressed. At several places on the platform, trap doors were installed so as to obtain any desired length of throw into what corresponded to a chute in the mine. The muck thrown through these doors rolled down the side of the waste dump, out of the way, so that the opening was always clear. A track was laid along the side of the dump at the platform level, so that tests could be conducted in which the shoveler loaded the muck into a car, which he then had to tram a distance of about 100 ft., dump, and return to the muck pile again.

Tests were carried on for 2 mo., three different shovelers, taken from the mines, being observed. Each of these men was warned that he had to work at his best speed, all during the job, but that he was not to overtax himself. He was told that when he became tired he was to take a few moments rest, as it was better for him to rest at intervals than to try to work all the time, at the expense of speed and capacity.

Shoveling Directly into a Chute. All of the underground shoveling tests may be classified under one of three headings, shoveling directly into chutes, shoveling into wheelbarrows and tramming to chutes, and shoveling into cars and tramming to chutes. Each of these series was conducted independently of the others, and was complete in itself. The men under observation worked for periods varying from 1 to 8 hr., and for each length of job they threw or trammed the muck over a wide range of distances, with various types and sizes of shovels. In all the underground tests, the work was done under the actual mining conditions, with the one exception that the men were always under observation and consequently were working at a good speed for the full period of the test. In no case did the men overtax themselves and we feel confident that all tonnages obtained and indicated on the charts are easily obtainable by a good, but not exceptional, Mexican laborer after he has been

properly instructed, and under close and intelligent supervision.

It soon became evident that the great majority of shovels being tested were not suitable for efficient work, and although we continued to work with them to some extent, we have charted only the work of the No. 4 shovel, which handles the 21-lb. load, together with the No. 2 scoop, which was held in high esteem by many of the men in the operating department. In each of the charts, the results obtained during the surface tests are plotted alongside of corresponding results from underground, in order to accentuate the adverse effects of underground conditions on shoveling capacity.

In Fig. 286 will be found the number of shovels per minute thrown into a chute at a distance of 8 ft. from the ore pile for

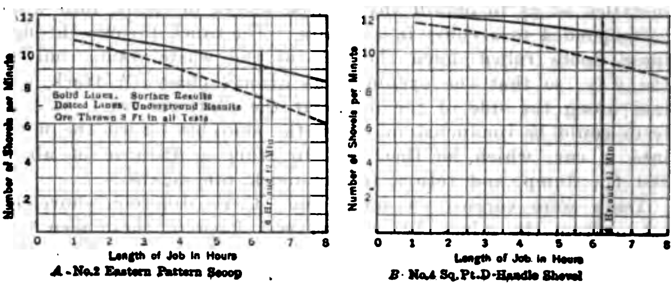


Fig. 286. Effect of Length of Job on Number of Shovels per Minute.

jobs varying in length from 1 to 8 hr. In all of these charts, the length of job should be understand to mean the total working time, and when it is said that the length is 4 hr., the man was actually occupied at shoveling ore for 4 hr., and then his work was finished. All points on the curves are corrected averages for the time periods to which they correspond.

In connection with Fig. 286, the following facts will be noted: For all lengths of job, the number of shovels per minute is greater with the No 4 shovel than with the No. 2 scoop. Both on the surface and underground, the speed of shoveling decreases more rapidly with the scoop than with the shovel, as the length of the job increases. A man working with a scoop underground can perform at only 72% of his speed on surface for 8 hr. while with a No. 4 shovel, he can work at 82% of his surface speed. The percentage reduction in speed between surface and underground work is the measure, in part, of the effect of mine air,

powder gas and smoke, temperature, humidity, and poor light, Under the same condition of work, the difference in speed between the No. 4 shovel and the No. 2 scoop is due to the difference in the load handled. For short lengths of time, the difference in working speed between a scoop and a shovel is so small that, disregarding rest periods, the scoop is a slightly greater tonnage mover than the shovel; but for longer periods, the difference in speed is such that the shovel with its smaller capacity moves more muck than the scoop.

Fig. 287 indicates the manner in which the length of throw will affect the speed of the shoveler. The decrease in shoveling speed on the surface amounts to an average of 2.5% for every foot increase in distance thrown in the case of the scoop, and

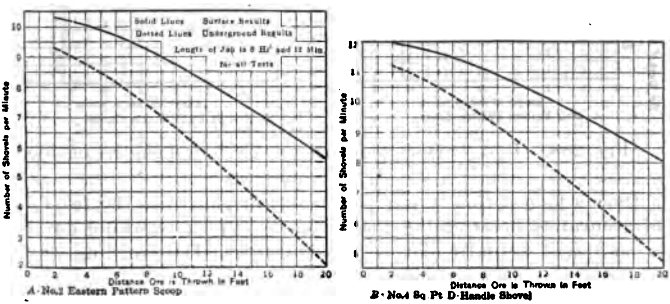


Fig. 287. Effect of Distance Thrown on Number of Shovels per Minute.

1.8% for the No. 4 shovel. Underground, the working speed is decreased more rapidly, being respectively 4.4% and 3.2% per foot increase in throw. The rate of decrease in shoveling speed, both on the surface and underground, is greater for the heavily loaded scoop than for the shovel.

To find the average shoveling speed for any length of job and for any distance that the ore has to be thrown, the number of shovels per minute for a throw of 8 ft., for the proper period, can be obtained from Fig. 286; this can be increased or diminished by the proper percentage obtained from Fig. 287, depending on whether the distance is less or greater than 8 ft.

Fig 288 shows the amount of rest required for shoveling jobs of various lengths. The scoop again has a negative effect both on surface and underground, causing a man to use up more time in resting than with a No. 4 shovel. The rest period, as considered here, is made up of the time consumed in delays, the

time actually spent in resting, during which the man may smoke a cigarette and sit down for a few minutes, and the time used in loosening the muck pile, scraping up the dirt on the shoveling plat, or doing other light work, not actually shoveling, but closely related to it.

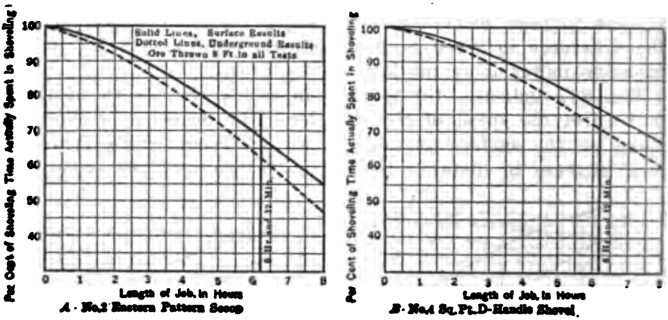


Fig. 288. Rest Period Required for Various Lengths of Job.

Over a long period it was possible to demonstrate the feasibility of accurately determining the percentage of the working day that a man will actually devote to shoveling. The working day at

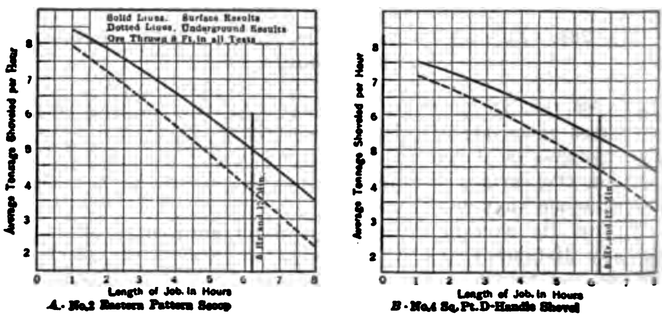


Fig. 289. Average Tonnage Shoveled per Hour for Any Length of Job.

the Burro Mountain mines is 8 hr., ½ hr. of which is given up to the lunch period, leaving 7½ hr. as the total possible working time. It was found that of this 7½ hr., the man actually worked at shoveling for 82.5% of the time, or for 6 hr.

and 12 min., and on all the charts involving time, this particular length of job has been designated by a special line. The remainder of the possible working time, or 17.5%, is spent on other work, quitting early for lunch or to leave the mine or commencing to work late at beginning of the shift or after lunch.

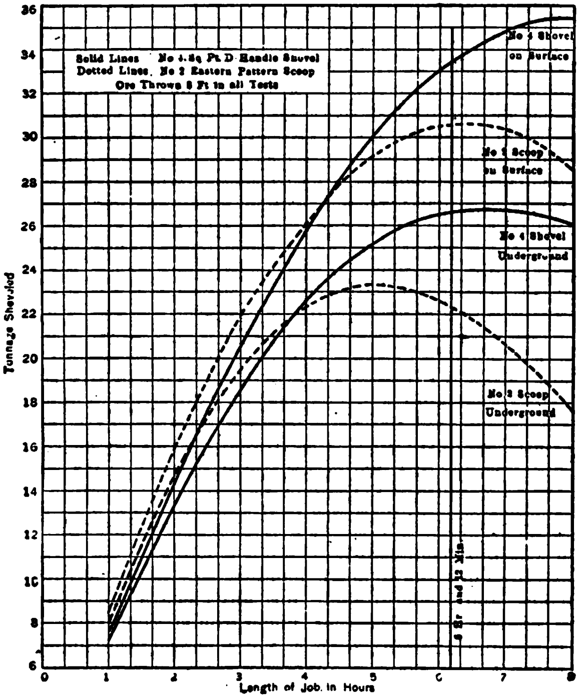


Fig. 290. Comparison of Worker of No. 2 Scoop and No. 4 Shovel

Fig. 289 gives the average tonnage per hour to be expected of a man throwing the muck a distance of 8 ft. over any period of time; and Fig. 290 gives the total tonnage shoveled for any period, over the same distance.

Fig. 291 shows how the time of shoveling one shovelful of ore is influenced by the length of the job, with the length of throw remaining constant. In chart B, the total time of handling

one shovelful of muck has been divided into its component movements. The lines representing the work of penetrating mass, lifting mass, and return, show a constant increase as the length of job increases. The actual increase in the time of each movement is not due so much, we think, to a decrease in the speed of making the move, which probably is fairly constant, as it is to an ever-increasing period of rest taken at the beginning and end of each movement, which, however, was too short to be accurately timed. Throwing mass is not influenced as much as the other moves, as the muck must be thrown along a definite path, which is limited to distance and height, and hence a constant speed must be maintained to carry it over.

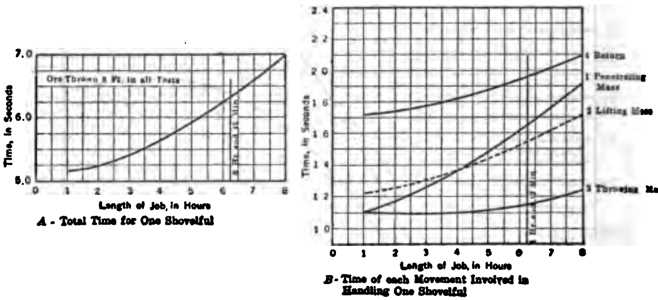


Fig. 291. Time Consumed in Handling One Shovelful of Muck with No. 4 Shovel Underground.

The reader will be well repaid by a careful study of Fig. 290 and the following points should be noted:

1. The difference in tonnage handled by the same shovel, on the surface and underground, for any length of job, is the measure of the bad effects of underground conditions. For a job of 6 hr. and 12 min., with a No. 4 shovel, the underground work is 20.5% less than on surface.

2. The difference between the amounts shoveled with the No. 2 scoop and the No. 4 shovel, under same conditions, is the measure of the effect of the difference in load handled by the man.

3. Each line on this chart shows a peak at some particular length of job, and the total tonnage shoveled for any greater period than this is actually less. The point at which this peak occurs should be termed the "economic shoveling day," and a company should not require its men to work at shoveling any longer than this, except in emergency cases.

4. The presence of this peak accords with the experience of many superintendents and managers, who state that their men do more work in an 8-hr. day than they did on an old 10-hr. basis.

5. The "economic shoveling day" is about 6⅓ hr., with a No. 2 scoop on the surface, and 5⅓ hr. underground. With a No. 4 shovel, on the surface 8 hr. is about the proper length of day, while underground 6⅔ hr. seems to be about correct. As the men actually shovel only 6⅕ hr. per day on an average and as their other work is generally of a very light nature, the 8-hr. day with the correctly proportioned shovel is probably the best; but with a scoop it is certainly too long.

6. For work on the surface, on jobs lasting longer than 4⅔ hr., the No. 4 shovel is superior to the scoop. Underground the No. 4 shovel demonstrates its superiority for jobs longer than 3⅔ hr. The scoop then may be considered as a task shovel for short-time jobs, but even here, its value is only slightly greater than the No. 4 shovel, besides tiring the man so that he is unfit for other work when the shoveling task is finished. There is also the additional danger of having some men continually trying to use the scoop for the full shift, thinking that the amount of work (and hence the amount of pay in the case of contract and bonus systems) is greater as the size of the shovel increases.

The following formulas show the manner in which use is made of the figures presented in the preceding diagrams:

Let W = weight of load on shovel, in pounds;
N = number of shovels per minute:
P = per cent. of time actually shoveling;
L = length of job, in minutes;
T = total tonnage shoveled;
n = number of shovels per minute for an 8-ft. throw;
p = per cent. increase or decrease due to various lengths of throw;

$$\frac{W \times N \times P \times L}{2000} = T \qquad N = n\ (1.00 \pm p)$$

Example 1.—What will be the total tonnage handled, using a 21 lb. load shovel, throwing the ore 8 ft., underground, for a job of 5 hr. duration? Chart B, Fig. 286, shows that for 5 hr. a man will average 10.1 shovels per minute, and Chart B, Fig. 288, shows that he will actually shovel 79% of the 5 hr. period, therefore:

$$\frac{21 \times 10.1 \times 0.79 \times 300}{2000} = 25.1\text{ T.}$$

Example 2.—What will be the total tonnage handled, using a 21-lb. load shovel, throwing the ore 15 ft. underground, for a job of 6 hr. duration? Chart B, Fig. 286 shows that for 6 hr. a man will throw a distance of 8

ft. at the rate of 9.6 shovels per minute, Chart B, Fig. 287, shows that increasing the distance to 15 ft. reduces the capacity by 27.4%, therefore:

$$N = n(1.00 \pm p) = 9.6(1.00 - 0.274) = 7;$$

hence,

$$\frac{21 \times 7.0 \times 0.73 \times 360}{2000} = 19.3 \text{ T.}$$

Shoveling into a Wheelbarrow. The charts presented in this series, Figs. 292 to 295, follow as closely as possible the series just discussed, but offer only the results obtained with the No. 4 D-handle shovel. It was soon discovered that a throw of 3 ft. to the wheelbarrow gave the best results as far as number of shovels per minute and rest periods required were concerned,

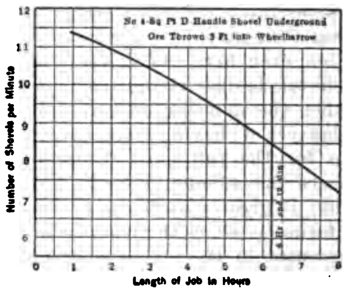


Fig. 292. Effect of Length of Job on Number of Shovels per Minute.

and in all subsequent work the ore was thrown into the wheelbarrow from this distance. It will be noted that, in Fig. 292, for any length of job, the number of shovels per minute are less than when throwing 8 ft. into a chute; this is due to the fact that the shoveler must place each shovelful carefully to keep wheelbarrow from spilling its contents and to make it ride easily.

Chart A, Fig. 293, shows the length of time consumed in tramming and dumping a wheelbarrow over any distance and chart B shows the average tramming speed developed for any distance. For this chart careful determinations were made of the distance in which it takes a man to acquire full speed and the distance in which, after having attained full speed, he can make his stop. The full-speed rate of travel in stopes will average 165 ft. per minute. The wheelbarrow in use is the No. 7, which holds 3 cu. ft. and stands 21 in. above the floor at point of maximum height. The maximum load in a wheelbarrow should be about

300 lb. as larger loads are too exhausting, and lighter loads consume too much time in tramming and dumping.

Chart A, Fig. 294, shows the per cent. of time a man will work during any given working period, the length of tram in each case being 20 ft. The rest period is practically a constant

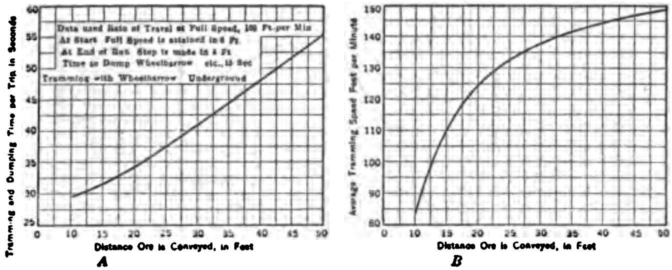


Fig 293. Effect of Distance on Time and Speed of Tramming.

proportion of any length of job, as that part of the tramming time in which the man brings the empty wheelbarrow back to the ore pile is virtually a rest period. For long trams, the work of tramming the loaded barrow is so heavy that a greater rest is required than is obtained on the return, and chart B shows

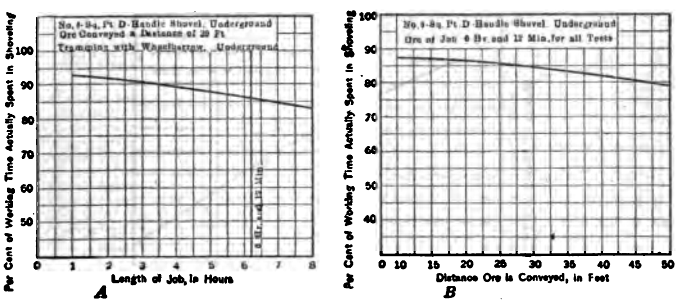


Fig. 294. Rest Period Required for Various Conditions of Work

how the rest period increases for a constant length of job, as the length of tram increases

Fig. 295 shows the tonnage to be expected of a man, based on Figs. 292 to 294, for any length of job, the length of tram being constant at 20 ft. This chart shows that the shoveler has

not quite reached his maximum capacity at the end of 8 hr. Two reasons are advanced for this: (1) As long as a man can

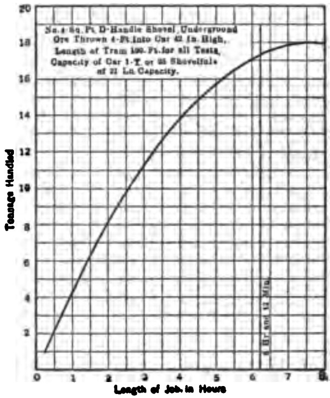


Fig. 295. Showing Capacity of a Shoveler Using a Wheelbarrow for Various Jobs.

throw the ore into a chute, he has a fairly direct throw from the ore pile to the chute, and with a car he has a definite path

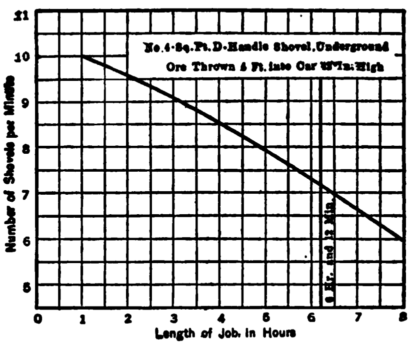


Fig. 296 Effect of Length of Job on Number of Shovels per Minute.

to traverse each trip. With a wheelbarrow, however, the direction and length of tram is constantly varying, as is also the

amount of interference from other trammers, timbermen, machine men, etc. The retarding influence of these factors increases as the length of the tram increases. (2) The sequence of operations, shoveling, tramming, dumping, etc. is of such short duration and

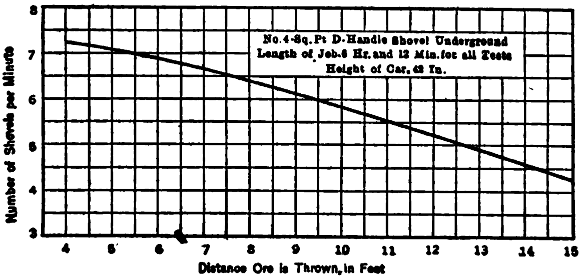


Fig. 297. Effect of Distance Thrown on Number of Shovels per Minute.

changes so often from one to the other that it is very hard to keep up any pace that may be set and probably an unnecessary amount of rest is indulged in for all periods.

Shoveling into a Car. Fig. 296 shows the number of shovels

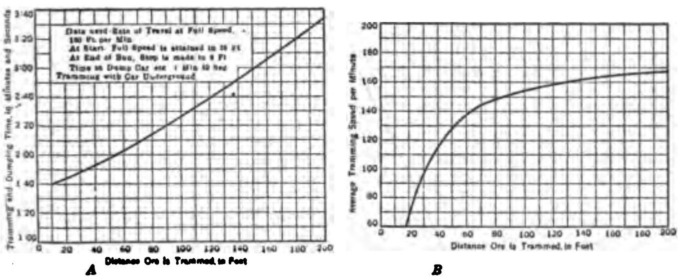


Fig. 298. Effect of Distance on Time and Speed of Tramming.

per minute thrown into a car for any length of job. In this series of tests the ore was thrown a horizontal distance of 4 ft. into a mine car 42 in. high; 4 ft. seems to be the best distance to maintain between car and ore pile, for a man to work to the best advantage. Due to the height of the car, the capacity of a shoveler is decreased, as compared to his capacity in shovels

per minute, when loading into a wheelbarrow. This decrease in shoveling speed amounts to about 8% per foot of height. The best type of car for a shoveler to use holds about a ton of ore, is

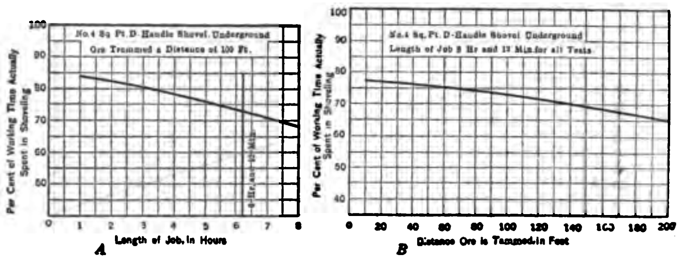


Fig. 299. Rest Period Required for Various Conditions of Work.

as low as is consistent with good design, certainly not over 45 in. in height, and is equipped with roller bearings, which should

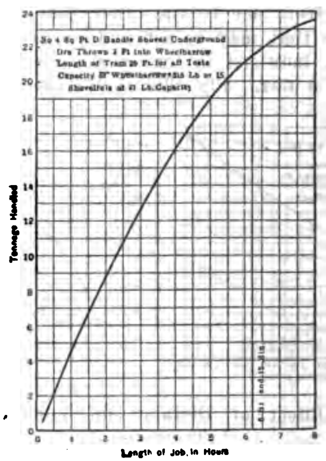


Fig. 300. Showing Capacity of a Shoveler Using a Car for Various Jobs.

be kept in the best of condition. Cars much larger than this are too hard to tram and cars much smaller use up too much of the shovelers' time tramming back and forth.

Fig. 297 shows the effect of having to throw the ore a greater distance than 4 ft. into the car, for a given length of job, using a No. 4 D-handle shovel. For every additional foot between the car and the ore pile, the height of the car remaining constant, the decrease in shoveling speed amounts to about 3.6%.

In Fig. 298, chart A shows the time consumed in tramming, dumping, and returning with the car, over various distances. Chart B shows the average tramming speed that will be developed for any distance over which the ore has to be conveyed.

Fig. 299A shows the amount of rest required for various lengths

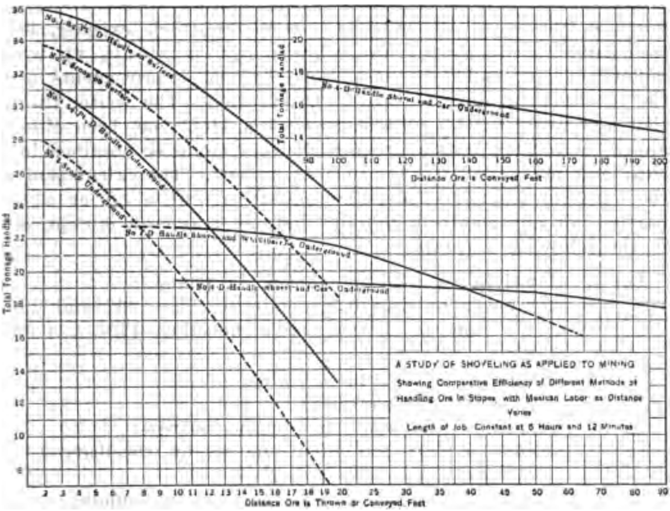


Fig. 301 Comparative Efficiency of Different Methods of Handling Ore in Stopes.

of jobs under constant conditions of length of tram, and distance and height through which the ore is thrown by the shoveler. For any length of job, as the length of tram increases, the amount of rest needed is increased as shown in chart B. Both of these lines, however, are quite flat, for a man can get very nearly enough rest as he returns each trip with the empty car.

Fig 300 shows the tonnage to be expected of a man mucking into a car and tramming a constant distance, for various lengths of jobs. It will be noticed that the economic shoveling day is

between 7 and 8 hr. and that the maximum average results to be expected of a mine shoveler under the given conditions have probably been reached.

Fig. 301 is made up for a uniform shoveling day of 6 hr. and 12 min. and shows the tonnage to be expected under average shoveling conditions for any distance that the ore must be thrown or trammed. The line representing the tonnage to be expected of a man with a wheelbarrow may not be entirely correct, especially as the length of tram increases. It is thought that up to 15 feet. the line is about correct but that it may slope off a little too rapidly beyond this point. On the other hand, the wheelbarrow is generally used where neither direct shoveling nor the use of a car, with its attendant track expense, etc., is feasible, consequently, the wheelbarrow is always at work under adverse conditions in a stope and no improvements over the results here tabulated are to be expected. The writer thinks that the work with a wheelbarrow in a stope has been closely approximated but that a greater efficiency could be obtained in a clear and unobstructed way, such as a drift. The calculation of the tonnage expected when tramming either with a car or wheelbarrow, for any length of job and distance trammed, is expressed in the following formulas:

Let W = weight of load on shovel, in pounds;
N = number of shovels per minute, Figs. 292 and 296;
P = per cent. of time actually shoveling, Figs. 294 and 299;
L = length of job, in minutes;
T = total tonnage shoveled;
a = time to load one car or wheelbarrow;
b = time to tram and dump one car or wheelbarrow, in minutes, Figs. 293 and 298;
c = load on one car or wheelbarrow, in pounds;

$$\frac{c}{W \times N} = a \qquad \frac{\left(\frac{L}{a+b}\right) \times c \times P}{2000} = T$$

Example 1.—What will be the total tonnage handled, using a 21-lb. shovel and a wheelbarrow, and tramming the ore 20 ft. for a job of 5 hr. duration?

It is necessary first to find the time required to load one wheelbarrow, or $a = \frac{315}{21 \times 9.3} = 1.61$; then the total tonnage handled is

$$T = \frac{\left(\frac{300}{1.61 + 0.56}\right) \times 315 \times 0.88}{2000} = 19.16$$

Example 2.—What tonnage will be handled in 6 hr. and 12 min., using a car of 1 T. capacity and a shovel of 21-lb. capacity, tramming a distance of 100 ft.? As the time required to load one car is $\frac{2000}{21 \times 7.2} = 13.3$; the total tonnage handled is

$$T = \frac{\left(\frac{372}{13.3 + 2.43}\right) \times 2000 \times 0.73}{2000} = 17.26$$

TABLE 3.—SCHEDULE OF WEAR OF SHOVELS

Type of shovel	Used on	Tonnage handled by blades made of Chrome-nickel Steel	Secret Composition Steel	Common Carbon Steel	Extra Light Carbon Steel
No. 2 scoop	Iron sheet	1220	950	750	
No. 2 scoop	Rough bottom				
No. 2 scoop	Wooden mat	1500	1100	900	
No. 4 shovel	Iron sheet	990	770	620	250
No. 4 shovel	Rough bottom	1075	870		
No. 4 shovel	Wooden mat	1168	1000	730	340
Gage of steel in blade		15	13	14	16
Cost of shovel per ton handled, cent		0.0015	0.0018	0.0019	0.0026

Wear of Shovels. To determine the relative wearing qualities and the cost per ton for supplying the men underground with new shovels, different places in the mines were equipped with different makes and styles of shovels and the results carefully noted. At frequent intervals, these shovels were measured to detect the wear of the blade, and checked up to see that all were being used in the proper places underground; the tonnage coming from each place and the number of shovelers employed were also noted. Table 3 gives the results obtained with the different shovels.

The shovels made of chrome-nickel and special steel were excellent implements but the special steel shovel was considerably heavier than the other. Cracks developed along the form line of the chrome-nickel steel blade, on each side, but these did not impair the shovel's usefulness. The blades of the three other shovels bent easily with rough usage; while the blade made of extra light carbon steel wore very rapidly and the edges curled up almost immediately. The No. 2 scoop was used until its capacity had been reduced 25% and the No. 4 shovel, until its capacity had been reduced 9%. The cost of shovel per ton handled includes the cost of the shovel, supply-house handling, handling new shovels into mine, and disposal of worn shovels. We had hoped to be able to detect a difference in the main efficiency on account of the different styles and weights of shovels in use at this time, but owing to the constantly changing

conditions in the working places selected for the trials, no conclusive evidence was available.

The wearing quality of any shovel used on an iron sheet varies from 74% to 86% of the wearing quality of the same shovel on a wooden mat, the average being 82%. The wearing quality of a shovel on a rough bottom is about 90% of that on a wood mat. These figures are based on about 50 observed shovels underground.

Type of Shovel Adopted. Tests were conducted with square- and round-point shovels varying in size from No. 2 to No. 6 and with standard No. 2 scoops, to determine what size of shovel was best adapted to the work. For short jobs of less than 4 hr. duration, the No. 2 scoop and the No. 5 and 6 shovel were slightly the best from the standpoint of tonnage handled; but for jobs requiring more than 4 hr. for their completion, the No. 4 shovel was greatly superior, see Fig. 290. From the standpoint of "number of shovels per minute," work with a scoop is at all times slower than with a No. 4 shovel, see Fig. 286, and as the day progresses the percentage of time required for resting becomes greater with the scoop than with the shovel, see Fig. 288. The result is that although for short work periods, the larger capacity of the scoop brings the total tonnage handled above that of a No. 4 shovel, for long periods the increased amount of rest required when handling the heavier load serves to put the No. 4 shovel considerably in the lead as a tonnage mover. With shovels smaller than the No. 4, the number of shovels per minute was not increased and the amount of rest required was not decreased enough to make the smaller shovel superior for any working period. It may be stated as a generalization, that for shovels smaller than the 21-lb. load shovel, the tonnage handled per shift is approximately directly proportional to the shovel capacity; that is, if a man using a No. 4 shovel will handle 26 T. in an 8-hr. shift, with a No. 3 shovel which holds 91% of the load of a No. 4 shovel, he would be expected to shovel about 24 T. a shift. If the increased cost of shoveling with a smaller shovel, or one that has been worn, is balanced against the cost of putting a new shovel underground and discarding the old one, it will indicate the economic limit of wear of the shovels in use. We have, for the present, rather arbitrarily selected as the limit, a shovel of size No. 4, which has been worn to about 12 in. in length, or roughly a 9% to 10% reduction of capacity.

The lift of a shovel is very important. By "lift" is meant the amount of rise in the handle just behind the blade. A handle that is not very much bent at this point, but which goes off

straight, is said to have a low lift, while one that arches steeply is said to possess a high lift. To work with a shovel having a low lift the man must stoop down more each time to take a grip on his shovel after it has penetrated the mass, and the added movement takes longer, and requires a greater effort to lift the weight of the body and the load through a greater space. As a result, more rest is required in the course of a day. With a very low lift, the shovel is not well balanced and there is a tendency for it to turn over in the hand, especially if it is not loaded evenly. With a high lift, the man does not have to stoop so far to grasp his shovel, the amount of rest period is decreased, and the loaded shovel is better balanced, because its center of gravity is well below the line of the handle. A lift of 8 in. is the best, as with greater lifts the awkwardness of the throwing movement is considerably enhanced. The height of the end of the handle above the floor when the shovel blade is flat on the floor is of considerable importance, too; this is the measurement that the manufacturers call the "lift." In a short-handle shovel, the end of the handle should strike just above a man's knee, a height of 23 in., to give the most effective effort in penetrating the mass. With a long-handle shovel the height should be the same at a distance back of the blade, corresponding to the length of the short handle.

It is an advantage to have the weight of the shovel as low as is consistent with good material and length of life. Increasing the weight of the shovel slows up every motion involved in shoveling and increases the amount of resting required. However, it is not wise to go to extremes in the matter, as a very light shovel does not possess the strength and wearing qualities and the cost of replacement is greater than the advantage gained in shoveling speed. In a personal communication, Mr. Frank B. Gilbreth says: "The 21-lb. load refers to shoveling any kind of material anywhere, above ground or below ground, and this is the live load upon the shovel and does not include the weight of the shovel. I make this statement after having asked this question of Mr. Taylor. Obviously it would have been better if the data had been obtained on the basis of having the load, live and dead, combined in one figure."

As we lacked information, we assumed that Mr. Taylor experimented, at least in part, with stock shovels, which weigh about 6 lb. in the No. 4 size. Our experiments were conducted with shovels of both regular and special design, varying in weight from 4 lb. 10 oz. to 6 lb. 5 oz. and we found that shovels weighing between 5 lb. 8 oz. and 5 lb. 10 oz. give the greatest per man capacity. This is a total combined live and dead weight of

26 lb. 8 oz. to 26 lb. 10 oz. A shovel of this weight can be made very sturdily, the gauge of blade being No. 15 of some composition steel and the handles of best selected XX second-growth northern white ash. With heavier shovels, there is a distinct falling off in capacity; while for lighter shovels, although we could detect no difference in capacity, the wearing quality was poorer, due to lack of strength.

The use of the scoop is not advocated except where the material to be moved is so light that the scoop holds only 21 lb. Even for short jobs its use offers only a doubtful advantage, see Fig. 290. For shoveling on any sort of a mat or platform, the square-point shovel is the better; while for scraping down and working on a rough bottom, the round-point shovel should be used. Where there is plenty of room for men to work, the long-handle shovel of both square- and round-point pattern is superior to the short-handle. This is true for all distances and heights to which the ore has to be thrown, and the farther or the higher the ore has to be thrown, the more pronounced is the superiority of the long-handle type. D. J. Hauer says that where men are working in a free space they can do, on an average 10% more work with a long-handle shovel than with the short-handle; that the limit of throw, taking only one step, is 12 ft. with a long-handle shovel and 9 to 10 ft. with a short-handle shovel. We have checked Hauer on these points and find his statements on the relative efficiency of the two types of shovels to be substantially correct; but we found that it is economy to throw as far as 12 ft. with a short-handle shovel and 14 ft. with a long-handle. Unfortunately, however, most working places underground are very restricted in area and it is necessary to use the short-handle shovel. Where one man is shoveling in a drift, or one to each set of timber in a stope, the long-handle shovel can be used to advantage. Where men are working 2½ to 3 ft. apart, a short-handle shovel should be used. According to D. W. Brunton and J. A. Davis, in U. S. Bureau of Mines' *Bull.* No. 57, the minimum spacing of men working side by side in a drift should be 2.5 ft. Calling the performance of a square-point shovel on a wooden mat 100%, the efficiency of a square-point shovel working on a rough bottom is only 60% while with a round-point shovel an efficiency of about 70% may be maintained.

Fig. 302 shows the design considered best adapted to mining work. The blade should hold 21 lb. of broken ore as an average load. The approximate dimensions of blades for various ores are given in Table 2; the dimensions on the illustrations are for Burro Mountain ore. Both the square- and the round-point blades should be of standard shape, of No. 15 gauge at the point,

and of such composition that the shovel will handle not less than 1100 T. of medium hard ore when shoveled off a wooden mat. All blades should be of plain back type without rivets, the back strap being welded to the blade. Only best-grade second-growth, northern white ash should be used for the handle, which should be bent to the shape and dimensions shown. On short-handle shovels, the Dirigo, or split D, handle is preferred, as it is much stronger than the ordinary D handle.

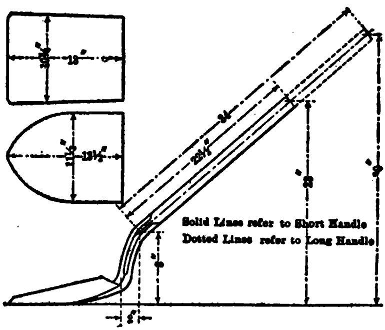


Fig.302. Design of Shovel Best Adapted to Mining Work.

Correct Shoveling Methods. A right-hand shoveler throws the ore from his right side. When using a short-handle shovel, he grasps the D handle with his left hand, the cross of the D being in the palm of the hand to obtain a good hold, and with the right hand takes a grip on the handle just back of the straps. Standing close to the material to be shoveled, he bends his back, shoulders, and knees, and assumes a squatting position so as to remain well balanced on his feet. The left hand grasping the D handle rests against the left leg just above the knee, and the right arm below the elbow rests on the right leg. Without moving the feet, the whole body is lunged forwards from this position, thrusting the shovel blade forcibly under the muck pile, and heaping it full. To elevate the full shovel, the knees, back, and shoulders are simultaneously straightened, the feet remaining motionless. To throw the ore into a car, after the shoveler has reached a nearly erect position, the shovel is raised farther by drawing up the arms, the left hand acting as a moving fulcrum, and the load is cast directly over the right shoulder without turning the body or moving the feet. To cast in a horizontal direction for any distance, the body must be turned part way

around to the right and a short step made in the direction of the throw; the load is cast by a swing of the arms, first slightly backward to obtain momentum and then forcibly forward to deliver the load.

When using a long-handle shovel, a right-hand man grasps the shovel close to the end of the handle with the left hand and places the right hand just back of the straps. The feet are placed, and the body assumes a crouching position with knees bent and the right elbow resting on the right thigh just above the knee. The handle of the shovel lies across the left thigh close to the groin and the left hand falls into position against the body near the waist. With a lunge of the body the shovel is then thrust under the mass of ore without moving the feet. To lift the mass on the loaded shovel, the back and shoulders are straightened and the load is brought up by using the left thigh as a fulcrum, over which the shovel handle works as a lever; the knees are then straightened to bring the shoveler into an erect position where the ore is cast directly over the right shoulder into a car as with the short-handle shovel. To cast the load horizontally, a turn to the right is made and a short step in the direction of the throw, exactly as with the short-handle shovel.

It is surprising what a small proportion of the men underground know how to use a shovel to the best advantage, and all sorts of tricks are resorted to in an effort to lighten the work. Among these are: Taking less than a shovelful each time, using the foot in an effort to force the shovel into the muck pile in the manner of using a spade, skimming a thin layer of loose dirt off the sides of the muck pile instead of energetically penetrating the mass to obtain a full shovel load, not holding the shovel properly, and taking two or three steps with each load.

To obtain the highest shoveling efficiency underground, every man hired as a shoveler should be placed in a particular stope or working place that is directly in charge of a shoveling boss. This boss should have had a large experience in shoveling, have learned correct shoveling methods, and should be able to instruct men and gain their confidence. Each man should be taught: (1) The necessity of using the correct type of shovel for any given purpose; (2) the proper way to handle a shovel; (3) the range of usefulness of wheelbarrow and car; (4) the advantage of using a platform to shovel from; when shoveling has progressed beyond the platform time should be taken to advance the boards or iron sheet and to scrape the broken ore forward onto the platform; (5) the mass of broken ore should be thoroughly loosened with a pick; it is waste of effort to try to shovel material that has become packed; (6) shoveling should be done at a good

steady pace, the speed depending on the length of the job; it is waste of time and energy to try to rush through the work; (7) in addition to the amount of rest inherent in the work itself, that is, the rest gained while picking down, tramming, etc., definite rest periods should be maintained during the day. When each man has been thoroughly instructed in the methods of shoveling, he should be placed in general run-of-mine work among the more experienced shovelers, so that another new man may take his place for instruction.

When possible to avoid it, a shoveler should never be made to work alone. Shovelers working in pairs produce the best results, as they set the pace for one another and compete to a large extent, besides, any laxness can be detected almost at once. Shovelers should be placed in groups of two, four, six, etc., so that the men can work in pairs. It is best not to have more than four men in any group, as with larger groups it is hard to watch the work of each man separately and they try to put the work off on one another. Best results are always obtained when the tonnage shoveled by each man, or small group of men, can be accurately measured at the end of every shift. When men are shoveling in a stope where there is room, they should be so placed that each can use a long-handled shovel; where the area is restricted, a short-handle shovel should be given to them and they should be placed so that a right-hand and a left-hand man can work together.

The ideal shoveling day is the period during which a man can rest at stated intervals and can produce the maximum tonnage by working at a steady pace for the full period, and yet not wear himself out, so that his health is impaired. It is obvious that a steady working pace for the full period is physically impossible unless the rest periods are excessive, in which case the total tonnage handled falls off; in other words, a man cannot do a good day's work and leave the job feeling as fresh as when he arrived. In all of the tests, the shovelers showed a decreasing efficiency, as the day advanced; rest periods brought up the efficiency, but after each successive rest period the efficiency did not advance to quite the same point as after the preceding period, and at the end of the shift it had reached its lowest ebb. Much work can still be done on this point, but after considering the amount of rest that is inherent in the work itself and the amount of added supervision necessary to maintain shoveling on a scientific basis, the tentative statement is made that, in addition to the lunch period, there should be two 10-min. periods of complete relaxation, one midway between the beginning of the shift and lunch time and the other midway between lunch and quitting time.

The wage in force at present at the Burro Mountain mines for

Mexican shovelers is $3.40 a day. Assuming that this is a fair wage for this class of labor, to put the men in the proper frame of mind to take kindly to the bonus system, the wage should be raised to $3.75 a day, an increase of 10.3%; this wage will be paid to them whether they make the required tonnage or not. If any man makes the tonnage required of him, his wage may be raised to $4 for that shift, an increase of 17.6% above the $3.40 rate, although this has not been designated in Table 4. If he produces anything over the required amount, he should be paid a bonus per ton, depending on the original task allotted to him. In order to make an increase of 50% over his old $3.40 rate, a shoveler will have to produce between 25 and 30% more than his allotment. Experience has shown that when a laborer receives an advance in wages of more than about 50 to 80% above

TABLE 4.— BONUS PAYMENTS TO BE APPLIED TO SHOVELERS. BASE RATE OF $3.75 PER DAY IS GUARANTEED TO MAN

Distance Ore is Thrown or Conveyed Feet	Shoveling into Chute			Shoveling into Wheelbarrow			Shoveling into Car		
	Average Tonnage Expected	Payment Rate for Average	Bonus per Ton Above Average	Average Tonnage Expected	Payment Rate for Average	Bonus per Ton Above Average	Average Tonnage Expected	Payment Rate for Average	Bonus per Ton Above Average
2	31.5	0.120	0.130						
3	31.0	0.121	0.131						
4	30.0	0.125	0.135						
5	29.5	0.128	0.138						
6	29.0	0.130	0.140						
7	28.0	0.134	0.144	22.7	0.165	0.175			
8	27.0	0.139	0.149	22.7	0.165	0.175			
9	26.0	0.144	0.154	22.7	0.165	0.175			
10	25.0	0.150	0.160	22.6	0.166	0.176	19.5	0.192	0.202
11	24.0	0.156	0.166	22.6	0.166	0.176	19.5	0.192	0.202
12	23.0	0.163	0.173	22.6	0.166	0.176	19.5	0.192	0.202
13	22.0	0.170	0.180	22.5	0.167	0.177	19.4	0.193	0.203
14	20.0	0.188	0.198	22.4	0.167	0.177	19.4	0.193	0.203
15	19.0	0.197	0.207	22.3	0.168	0.178	19.4	0.193	0.203
16	18.0	0.208	0.218	22.1	0.169	0.179	19.4	0.193	0.203
17	17.0	0.220	0.230	22.0	0.170	0.180	19.3	0.194	0.204
18	16.0	0.235	0.245	21.8	0.172	0.182	19.3	0.194	0.204
19	14.0	0.268	0.278	21.6	0.173	0.183	19.3	0.194	0.204
20	13.0	0.290	0.300	21.5	0.175	0.185	19.3	0.194	0.204
25				21.0	0.178	0.188	19.2	0.195	0.205
30				20.3	0.184	0.194	19.1	0.196	0.206
35				19.6	0.191	0.201	19.0	0.197	0.207
40				18.8	0.199	0.209	18.9	0.198	0.208
45				18.0	0.208	0.218	18.8	0.199	0.209
50				17.3	0.217	0.227	18.7	0.200	0.210
60				16.4	0.228	0.238	18.4	0.204	0.214
70							18.2	0.206	0.216
80							18.0	0.208	0.208
90							17.8	0.210	0.220
100							17.5	0.214	0.224

a fair wage, he tends to become shiftless and the increase does him more harm than good.

Fig. 301 shows that under good working conditions a laborer moving ore 20 ft. should use a wheelbarrow, and should move 21.5 T. According to Table 4, this man will receive $3.75 a day for any work up to 21.5 T., or at the rate of $0.175 a T. If he reaches the required 21.5 T., his wage will become $4, or at the rate of $0.185 a T, and for every ton over the required amount he will receive $0.185 a T. In each individual case, the man setting the standard of work should make sure whether there are any interfering elements that will prevent the man making the standard tonnage, in which case he should make a fair reduction.

In 1917, in a stope with raises spaced 25 by 65 ft. from which was mined 145,000 T., the shovelers average 8.5 T. a man. With wages at $3.40 a day, this shoveling cost $0.33 a T., assuming that the men were on other work for 17.5% of the day. Charts show that under the new system these men should have averaged 22.9 T. a man, for which they would have received $4 a day. This would be an average shoveling cost of $0.175 a T., or a gross saving of $22,475 for the year. Out of this gross saving would have to come the cost of, say, five special men, at an average salary of $160 a month, or a total of $9600 a year, to take care of this branch of the work. This sum deducted from $22,475 leaves a saving of $12,875, or a total shoveling cost of $0.239 a ton.

STEAM SHOVELS

Steam shovels may be divided into two classes, the railroad type and the revolving type.

The railroad type is mounted on standard gauge railroad trucks and is best adapted for heavy work. The boom of this type machine revolves, the rest of the machine remaining stationary.

The revolving shovel is a later development and its construction enables it to swing in a complete circle.

The railroad type shovels are built weighing as much as 140 tons, but about the most powerful steam shovel regularly built weighs 95 tons. For general work a 5-yard dipper may be used, but for iron ore or shale an extra heavy one of 2½ or 3½ yards capacity is better. The clear lift from the rail to the bottom of the open dipper door is 16 ft. 6 in. and the maximum width of cut 8 ft. above the rail is 60 ft. This shovel has a record output of four to five thousand yards per day. A steam shovel adapted to extra hard conditions is the 80-ton; the bucket used is generally 3 cubic yards for rock work or 4 yards for earth. The clear lift is 16 ft. and the width of cut 60 ft. A 70-ton shovel is

the one most in demand for heavy work under average conditions. It carries a 2 to 3½-yard dipper; the clear lift is 16 ft. 6 in.; width of cut, 60 ft. For work where the depth or amount of excavation is not great enough to warrant a 70-ton shovel a 60-ton is more economical. A 2½-cubic-yard dipper is generally used; clear lift, 15 ft.; width, 54 ft. A 45-ton shovel is designed for use on fairly heavy work, but where lightness and ease of transportation are essential. Capacity of dipper, 2 yards; clear lift, 14 ft.; width of cut, 50 ft. A 40-ton shovel is designed for lighter work or sewer excavation.

From observations made by the author on half a hundred steam shovels in actual operation during a considerable number of weeks the working capacities shown in the table on page 716 have been recorded. From these observations the average number of cubic yards per day excavated by all shovels in all materials was 934. This is perhaps less than may be expected on a well-managed job. A shovel should load a dipper 60% full every 20 seconds while actually working. About 50% of the time the shovel is held up by various causes, such as waiting for trains, moving ahead, waiting for blasts, and making repairs. With a 2½-yard dipper a shovel should, therefore, excavate 1,350 cubic yards in 10 hours.

The maximum width of cut given by shovel manufacturers is far greater than the actual average as recorded in observations made by the author. 70 to 95-ton shovels make an average cut of 28½ ft. wide. With a 30 or 40-ton shovel the average cut is not much more than 20 ft. in width.

The following notes on steam shovels are from "Handbook of Steam Shovel Work," which embodied a report made to the Bucyrus Co. by Construction Service Co., under the Author's direction in 1910.

Process of Loading. The process of loading consists in seizing the material after it has been reduced to a fit condition and placing it either in its ultimate position or upon a vehicle for the purpose of transportation. With hand shovels, unless the material be sand or gravel or very soft loam, it is essential that it be broken in order that the workmen may be able to handle it. With a steam shovel, however, much of the breaking can be done by the power of the shovel itself aided by teeth which are fastened to the dipper, so that, in many instances, rock which has been imperfectly blasted is further reduced by the crushing and tearing up of the teeth driven by the steam power of the shovel's mechanism. The steam shovel then is frequently called upon to perform not only its proper function of loading, but to a large extent the other process of breaking the material.

Great Variation in Steam Shovel Efficiency. In contrast to the above, the steam shovel is dependent for its work upon so many factors, any one of which may very greatly help or hinder it, that there is a far greater diversity of results than in the case of the hand work. Thus, on the standard basis for labor that we have assumed in this report, the direct labor cost alone for loading varies from ½ cent to nearly 13 cents per cubic yard, as observed.

Co-operation of Other Processes with the Steam Shovel Work. When a shovel is loading rock, for instance, its own efficiency is very dependent upon the manner and thoroughness with which the rock has been broken. The blasting must be of such quality as to break up the rock so that the shovel can easily handle it without leaving ridges that prevent the laying of the shovel track to grade. We have had experience with work where, because the blasting charge was not concentrated in the bottom of the holes, the ridges were so pronounced that the shovels were unable to operate more than 50% of the working day, the rest of the time being spent in waiting while the rock was "mud capped." Here inefficiency of shovel work was due entirely to improper blasting.

How Much Work Must There Be to Economically Justify the Use of a Steam Shovel? This question is vital on a large percentage of all excavation contracts. To answer it, simply calculate the total cost, including the cost of installing the plant, and divide this total by the cubic yards of material to be handled. A comparison of the quotients for the different methods will indicate which one should be followed.

General Conditions and Formulas.—*Repairs.* The cost of repairs should be apportioned to the work turned out rather than considered as a function of the age of the shovel. It will be higher for rock than earth work and higher for badly broken rock than for well blasted material. Thus, in a given material, the repair bill for a season's output of 500,000 cubic yards may be expected to be twice that in which the shovel loaded only 250,000 yards. Time alone does not affect the unit of cost of repairs. The reverse of this proposition obtains in the case of

Depreciation. If the machine be kept in proper repair the depreciation in its value is affected by time alone, regardless of the work that it is doing. Many concerns class the depreciation and repairs under one account, but this practice is inaccurate and misleading. There is great disagreeement among accountants as to how depreciation should be figured, and there are many so called depreciation formulas and "curves." The simplest to use, and one which for steam shovel work is satisfactory if proper

allowance be made for repairs, is the "right line formula," which is as follows:

$$X = \frac{(a - b)\frac{c}{d}}{a}, \text{ where } a = \text{original value,}$$

b = value on removal or sale,
c = time in use.
d = estimated life,
X = % of depreciation.

Then X divided by the output for the period c will be the cost of depreciation per unit of performance.

The working life of a steam shovel may safely be assumed at 20 years, and taking the first cost at, say, \$150 per ton, and its scrap value at \$10 per ton, the value for X, with a ten-year old shovel, would be

$$\frac{(\$150 - \$10)\frac{10}{20}}{\$150} = 46.67\% \text{ in the ten years, or } 4\tfrac{2}{3}\% \text{ per year.}$$

To estimate the depreciation per unit of output it is necessary to distribute this amount over the working time. The method of doing this is indicated under typical Standard Steam Shovel Work.

Interest. The interest on all the money invested in this work must be included as part of its cost. We have assumed this at the uniform rate of 6%.

Height of Bank. In different classes of steam shovel work, the height of the face to which the shovel can work has an important bearing upon costs. The reason for this is that the higher the bank, the larger the amount that the shovel can load without moving up.

Standard Rates. It is of no interest to contractor Jones how much contractor Smith paid his men, or for his coal a year or two ago, and Smith usually dislikes to have these exact rates published, on account of possible trouble within his own organization; but it is of importance to be able to compare the efficiencies of different methods in different places, so that any contractor using this volume may be able to estimate the value of any special methods herein described. Such comparison is valuable for making estimates on future work, and it is greatly facilitated by giving the data observed in terms of an assumed standard rate of pay for each class of men and materials. We have therefore given our cost data in these "standard" figures..

Formulas and Diagrams. Typical Standard Steam Shovel

Work. *Mathematical Analysis and Curves of Cost.* The following analysis of steam shovel work and the accompanying curves of cost are useful in enabling a rapid estimate to be made of the approximate cost of steam shovel work in progress or proposed.

d = time in minutes to load 1 cubic foot with dipper (place measure).
c = capacity of one car in cubic feet (place measure).
f = time shovel is interrupted while spotting one car.
e = time shovel is interrupted to change trains.
g = time to move shovel.
L = distance of one move of shovel.
N = number of shovel moves.
M = minutes per working day less time for accidental delays.
A or B = area of shovel section excavated in square feet.
R = cost per cubic yard on cars in cents, for shovel work only (place measure).
L A N = cubic feet excavated per day.
C = shovel expense in cents, one day, not including superintendence and overhead charges and not including preparatory charges.
n = number of cars in train.

(1) Time to load one car = d c.
(2) Time to load one train = n d c + n f + e.
(3) Number of trains for one shovel move $= \frac{L\,A}{n\,c}$.
(4) Time between beginning of one shovel move and beginning of next

$$(ndc + nf + e)\frac{L\,A}{n\,c} + g.$$

(5) $$N = \frac{M}{\left(dc + f + \frac{e}{n}\right)\frac{L\,A}{c} + g.}$$

(6) $$R = \frac{27\,Cd}{M} + \frac{27\,C}{M}\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$$

This is the equivalent of the equation R = md + b.

(7) Where $m = \frac{27\,C}{M}$, and

(8) $$b = m\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$$

We have assumed for the typical example a shovel valued at, say, $14,000, and the following daily expense:

	Per Year
Depreciation, 4⅔%	$ 653.34
Interest, 6%	840.00
Repairs, when working one shift	2,000.00
	$3,493.34

Per year of 150* working days, or $23.29 per working day	$23.29
Shovel runner	5.00
Craneman	3.60
Fireman	2.40
One-half watchman at $50 per month	1.00
6 pitmen at $1.50	9.00
1 team hauling coal, water, etc., half day, say, at $5	2.50
2½ tons coal, at $3.50	8.75
Oil, waste, etc., say	1.50
	$57.04

It appears that the equation: $R = md + b$, is that of a straight line. Now since in this equation $m = \frac{27\ C}{M}$ and $b = m\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$ all quantities involved in the equation excepting d are, or are assumed to be, constant. The data upon the value of these quantities furnished by the accompanying reports have been presented in graphic form with all influencing factors noted on the five plates, A, B, C, D and E, bearing the heading *for use with cost curves.* See pages 701–704 inclusive.

Plate A indicates the time to load one cubic yard, place measure, in various kinds of material. Plate B deals with the quantities e, average time shovel is interrupted to change trains. For use in plotting the equation above, those average values of e, n, c and f, involved in ordinary contracting work where side dump cars are used, have been tabulated separately on plate C. It will there be seen that the average value for e, the time between trains, is 4 minutes. The average number of cars per train, or $n = 10$. The commonest form of contractors' side dump car is of 4 yards water measure, or 2.5 yards place measure capacity,† and we therefore take $c = 67.5$ cubic feet. The ordinary value of f is zero, since the cars are almost invariably spotted while the shovel is swinging and digging. Plate D deals with the values of M or the working time, including actual shovel time, waiting for trains, and moving up, but not accidental delays. Plate E deals with the time of moving up, an average value for which is 8 minutes.

The constants having been thus established, three sets of curves have been plotted on the plates headed *cost curves*, I, II and III, one for each of the three values of L A 1,500, 3,000 and 6,000 cubic feet (L being the average shovel move, 6 ft., and A the area of the dug section in square feet). Each of these sets of curves has been plotted for values of M, ranging from two hours to ten

* For various reasons, such as weather, lack of continuous work, transportation of plant, etc., we have assumed the average working year as composed of 150 working days. This, of course, will be greatly affected by local conditions.

† This is a general average. It varies a good deal with the character of the material handled.

hours by hourly intervals, between which intervals our observed values (see plate C) fall.

We have found it much more convenient to make use of our data when arranged in this manner, both for field work and for the purposes of the estimator, than when expressed in long tabulations. Moreover, when cost data are presented in the detailed form contained in this volume they are applicable to a far wider range of new conditions than when simply given in totals as records of cost. Attempts have been made to discredit cost data on the ground that they are of no use to anyone except him who did the work or made the original observations, or on the ground that to a reader who has perhaps never seen the job at all there will be so many unknown conditions, that when applying the data to his own work he cannot be sure of having conditions sufficiently similar to make comparisons safe. Moreover, skill in management varies greatly with different organizations, and a reader may not have the same ability in organizing or handling work as some of the people whose performance has been herein described. This is very true, and if the reader can do as well as any one of several of the managers whom we met in getting up these data, he may be proud, as well as wealthy; but cost data on any work, if presented in sufficient detail and with clearness, will be useful to any man, good, bad, or indifferent, who will intelligently study them. If he attempt to proceed with improper study of the data or of the work that he is trying to do himself, he will fail just as he would without the data, which in all cases must be taken with intelligent discrimination.

In the formula for steam shovel loading cost are some ten quantities that vary on different pieces of work. Some of these are dependent on the kind of material and equipment, some depend on the efficiency of the management alone, and some few are affected by conditions beyond control or foresight, such as weather. The first two can be "standardized" and the other must be estimated by us for purposes of illustration and by the reader for his own use. Even in the case of weather, there is not as much uncertainty as would at first appear, for over a long working season the number of days suitable for operating may be pretty well estimated in most climates by going over the Weather Bureau records for the neighborhood.

Because the meaning and general bearing of a mass of data can be grasped by looking at charts much more readily than by any other method known to us, we have used them in this volume.

Standard Assumptions. These have been made to facilitate the chart work, and because from our experience they are entirely justified in practice. When, for example, we assume that the

time to move a shovel is four minutes, though some men take fifteen, and a few two or three, we are justified by a vast number of cases in which the moving was actually done in four minutes. The assumptions for "A" depend upon the field conditions, and the reader must use the particular plate that most nearly represents the section area of his job, or else must make up his own.

Uses of Cost Curves. There are two important uses to which these curves of cost can conveniently be put.

1. Estimating the cost of proposed work.
2. Checking up the cost of work under way.

In estimating we may proceed as follows:

Assuming that the proposed work is to be a railroad cut in rock, with average equipment, there are then only three quantities to decide upon, namely, L A, 27d and M. The area of the shovel section being assumed at 250 square feet and the average distance of move being 6 feet, L A will equal 1,500 cubic feet. Now refer to plate A and select a fair value for the time of loading one cubic yard in rock work. Suppose 30 seconds be chosen. Next refer to plate D for the proper value of M to use for rock work. The average value is 8 hours (80% of 10 hours). The cost per yard in cents can now be read directly on cost curves, plate 1. With abscissa (27d) as 30 seconds glance upward till the vertical line through 30 seconds intersects the 8 hour, M line. Then on the left opposite this point of intersection read 9½ cents as the cost per cubic yard loaded, place measure.

It may be noted here that with respect to the two important items of time to load 1 cubic yard with dipper and values of M, the cost curves are perfectly flexible. Variation in the value of the constants may be allowed for by proper choice of M. In connection with the formula it is interesting to note the effect of decreasing the carrying capacity of each train, other conditions remaining the same. Suppose the carrying capacity to be decreased from the average, 10×2.5 yards $= 25$ cubic yards to 8×2 yards $= 16$ cubic yards, place measure, what would be the effect upon the cost per cubic yard? The new cost per cubic yard, place measure, would be 10.6 cents against the former 9.5 cents, an increase of 1.1 cent per yard, or 10%.

To use the curves for checking the cost of work in progress proceed as follows: The field operations are few and simple. Find the average time per dipper swing. Knowing the rated capacity of the dipper and the character of the material, a glance at the tabulation near the top of plate A will give the ratio of dipper capacity, place measure, to dipper capacity, water measure, and by using this factor the average capacity of dipper,

place measure, can be obtained, and thence the time to load 1 cubic foot or yard. Suppose for instance the average time per swing to be 25 seconds, material earth, and capacity of dipper $2\frac{1}{4}$ yards. On plate A, under heading "Ratio of $\frac{\text{place measure}}{\text{water measure}}$" we find for earth the average value for $\frac{\text{place measure}}{\text{water measure}}$ given as 0.53. Therefore $2\frac{1}{4} \times 0.53 = 1.2$ yards per swing or 2.88 yards

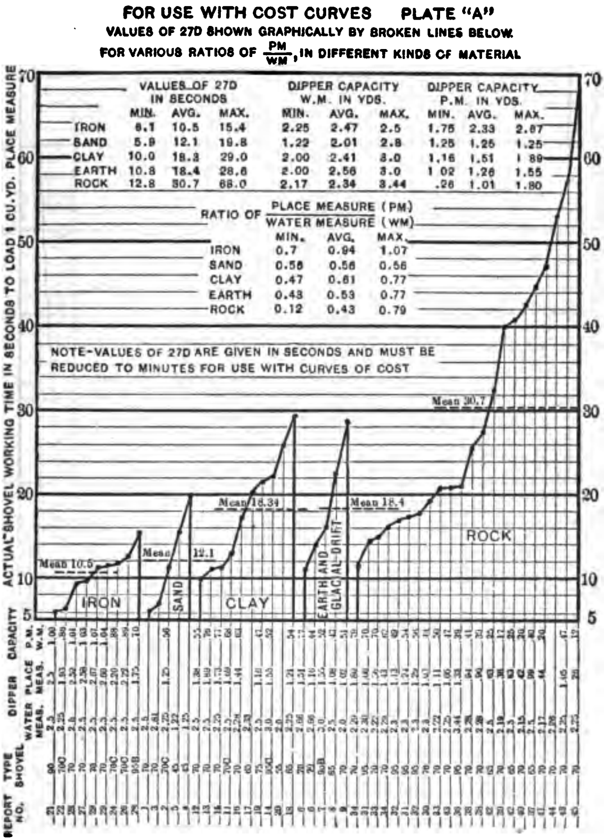


Fig. 303

per minute, or .35 minute per cubic yard. Make some rough measurements to determine the approximate area of the shovel section

FOR USE WITH COST CURVES PLATE "B"
VALUES OF "e" SHOWN GRAPHICALLY
AVERAGE TIME TO CHANGE TRAINS

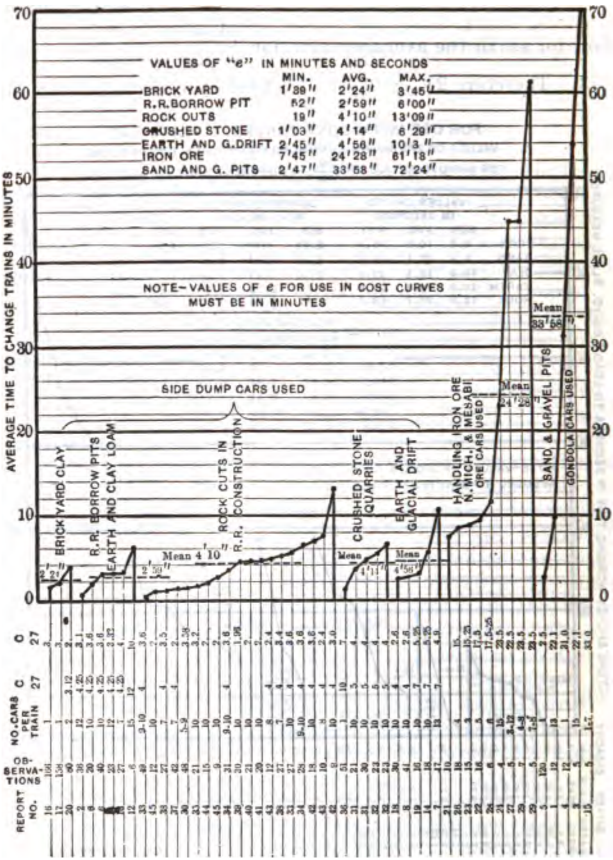
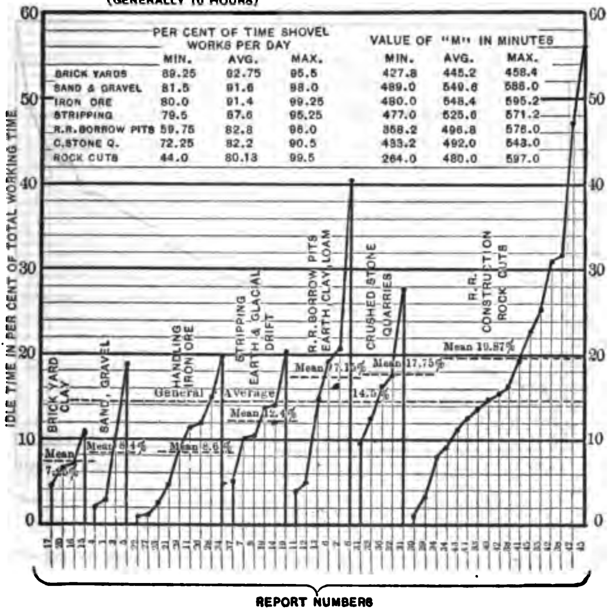


Fig. 304

and multiply this area by the length of move up and get L A, say 3,000. Then, from previous observations or by an estimate of M, get the time worked per day, less accidental delays, say 9 hours.

Now take cost curves, page 26, and with .21 as abscissa read opposite the line for $M = 9$ hours, 6 cents as the cost per yard place measure. If the constants in the formula do not agree closely enough with actual conditions, allow for this by choosing a suit-

FOR USE WITH COST CURVES PLATE "D"
AMOUNT OF IDLE TIME SHOWN GRAPHICALLY IN PER CENT OF TOTAL TIME WORKED EACH DAY
VALUES OF "M" TO BE TAKEN FROM THIS TABLE
"M" = ACTUAL WORKING TIME OF SHOVEL
TO FIND "M" TAKE VALUE PLOTTED BELOW, SUBTRACT FROM 100% AND MULTIPLY RESULT BY TOTAL WORKING TIME PER DAY. (GENERALLY 10 HOURS)



	PER CENT OF TIME SHOVEL WORKS PER DAY			VALUE OF "M" IN MINUTES		
	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.
BRICK YARDS	89.25	92.75	95.5	427.8	445.2	458.4
SAND & GRAVEL	81.5	91.6	98.0	489.0	549.6	588.0
IRON ORE	80.0	91.4	99.25	480.0	548.4	595.2
STRIPPING	79.5	87.6	95.25	477.0	525.6	571.2
R.R. BORROW PITS	59.75	82.8	96.0	358.2	496.8	576.0
C. STONE Q.	72.25	82.2	90.5	433.2	492.0	543.0
ROCK CUTS	44.0	80.13	99.5	264.0	480.0	597.0

Report No. 15 Worked in Slag
Report No. 43 Rock Cut on Soo Canal Widening

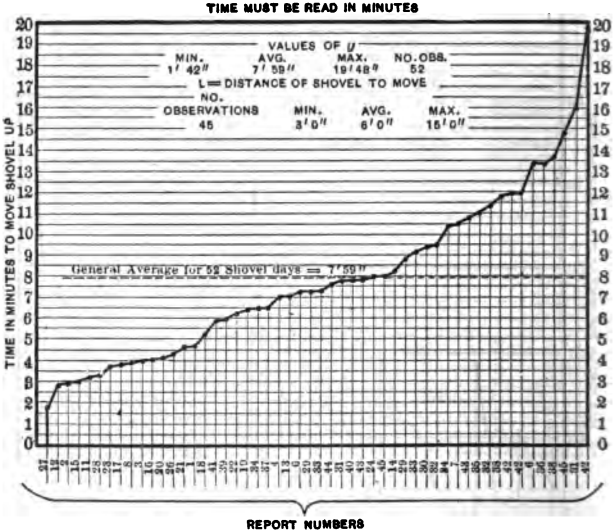
Fig. 305

able value of M. or substitute directly in the equation for cost.

Note that the above costs do not include superintendence or overhead charges, and cover only the cost of loading. Transportation, dumping, spreading and preparatory costs are not included.

These plotted charts have been given to assist the man who is accustomed to charts to use the observed data contained in this volume. By their use it is much easier to pick out the conditions that fit any particular piece of work, or a particular example to fit the conditions of the work to be done, and thus make the data available with less time than would be necessary if all the figures were given in tables.

FOR USE WITH COST CURVES PLATE "E"
VALUES OF "g" SHOWN GRAPHICALLY AS TAKEN FROM THE VARIOUS REPORTS
g = TIME TO MOVE SHOVEL UP
TIME MUST BE READ IN MINUTES



NOTE—Shovel on Report No. 9, Engaged in Sewer Excavation, Averaged 33' 45" to Move Up. It was Moved on Wooden Rolls

Fig. 306

It should be particularly noted that for plotting the two coordinates certain assumptions are necessary because there are a large number of variables in the theoretical steam shovel formula. Thus, we have made three plates — one where the expression L A is 1,500 cubic feet, one where it is 3,000, and one where it is 6,000. We have also made an assumption of $57.04 for the value of C. Where the shovel differs very much in type from the one mentioned or where the rates of labor are very different from those

assumed, it will be necessary to compensate for the difference between the new value of C and the one that we have used in the

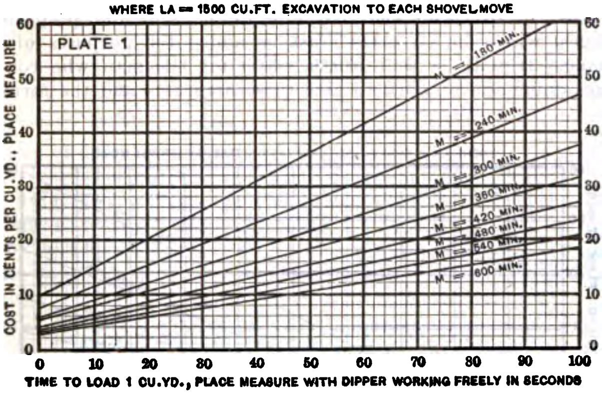


Fig. 307

diagrams. The easiest way to do this is to multiply the figures taken from the diagrams by the ratio between the new value of C

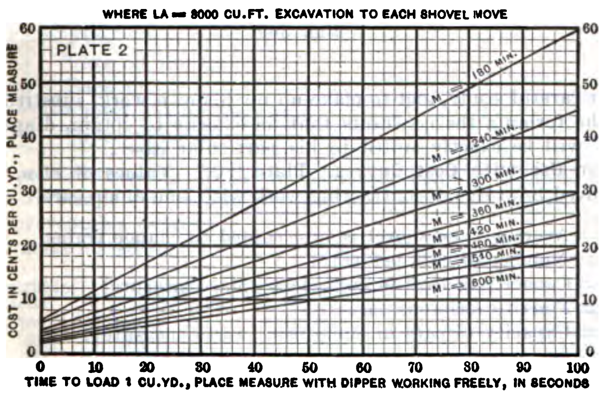


Fig. 308

and the assumed one. Thus, if the shovel costs per day turned out to be $65 instead of $57.04, and the diagram should give a cost

per cubic yard for loading of 12 cents, we would have for our charge 12 cents multiplied by \$65 and divided by \$57.04, or 13.67 cents per yard. As heretofore indicated, this does not include the cost of overhead charges, superintendence, and preparatory charges, which in all cases must be added for purposes of estimating. It will be well worth while for the man who contemplates doing shovel work to give these diagrams and the formulas

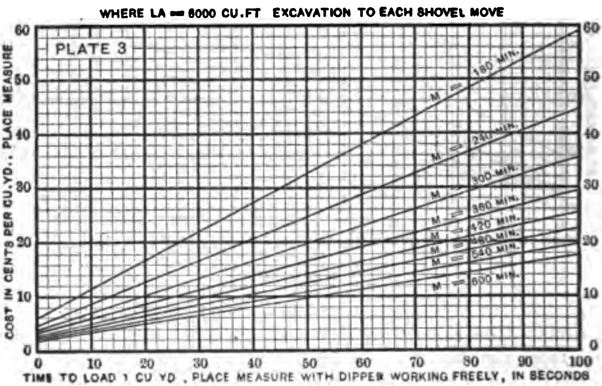


Fig. 309

most careful study, and to make up for his own work, substituting in the formula the constants that he expects to obtain, diagrams that will be exactly suited to his particular case.

For Use with Cost Curves. Plate "C." Values of *e*, *n*, *c*, *f*, involved in ordinary contracting work with side dump cars.

e = Average time shovel is interrupted to change trains.
n = Number of cars per train.
c = Capacity of cars in cubic feet (place measure).
f = Time to spot one car.
c' = Capacity of cars in cubic feet (water measure).

	Values of *n*			Values of *c*				
	Min.	Avg.	Max.	Min.	Avg.	Max.	*f*	*c'*
Brick yard clay	1	1-2	2	54	72	81		...
R. R. borrow pits	7	11	15	83.7	126	270		151
Rock cuts	7	9	12	54	75	97.2		[illegible]
Crushed stone quarries ..	1	10	10	108	124	189	Zero	162
Earth and glacial drift ..	10	10-11	13	70	108	141		157
Iron ore	3	7	12	270	540	675		540
Sand and gravel pit	1	7	15	67.5	598	891		...

General average of e, n, c, f, c', as follows

	No. of Obs.	Minimum	Average	Maximum
e	35	.25 min.	4.00 min.	13.5 min.
n	35	5.0 cars	10.00 cars	15.0 cars
f	0	0	0	0
c	35	2 yards	4.00 yards	10.00 yards
c'	27	4 yards	5.00 yards	12.00 yards
c/c'	27	0.5	0.8	0.95

Whistle Signals for Steam Shovel Work. A list of the various causes of delay should be kept by the shovel runner, and reported daily, with the duration of each, so that the relative importance of the different causes may be known, and a standard remedy adopted. Whenever such a remedy is needed, the shovel runner can call for it by a whistle signal. The following is a convenient code for these signals, a long toot being indicated by a dash, a short one by a dot:

—	Pit crew get ready to move shovel.
— ·	Get ready to mud cap.
— · ·	Get ready to block hole.
— · · —	We need coal.
· — ·	We need water.
· ·	Waiting for cars (useful to help in spotting cars when dinkey man cannot see hand signals).
·	Stop.
— — —	All ready to blast.
· · · ·	Fire.
· · — · ·	Cars off the track.
· · ·	Back up.
— — · ·	Shovel has broken down.
· — —	Superintendent's call.

A code of these signals in the shovel cab, and one in the hands of each foreman, will be sure to save money by the elimination of the preventable delays.

A make of steam shovels is priced as follows:

Weight in tons	Capacity of dipper, yd.	Effective pull on dipper, lb.	Approx. ship. wt. in lb.	Price f. o. b. Wis.
103	3½ to 5	84,400	207,000	$33,900
91	3½ to 4½	75,300	182,000	30,200
80	2½ to 3½	67,700	159,000	27,100
68	2½ to 3	56,000	136,000	23,900

The revolving shovels may be had in two general sizes, large and small shovels.

One make of revolving shovels is furnished in three standard sizes of the large class. The working weight of the smaller one is 160.5 tons. It is equipped with a 60-ft. boom, a 38-ft. dipper

handle, and operates a 2½-yd. dipper. The intermediate size weighs 214 tons, is equipped with a 75-ft. boom, a 48-ft. dipper handle, and operates a 3½-yd. dipper. The largest size weighs 336 tons, is equipped with an 80-ft. boom, a 58-ft. dipper handle, and operates a 6-yd. dipper.

The capacities of the dippers as given above are the struck measure. Heaped, the dippers have the following respective capacities: 2¾, 4½ and 7½ cu. yd.

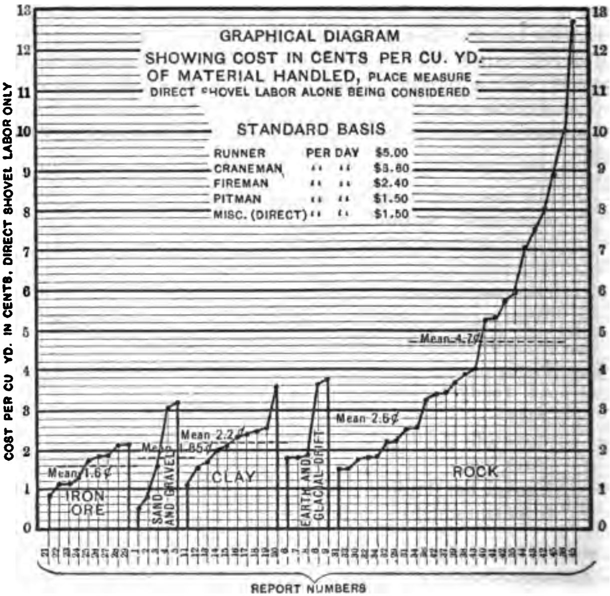


Fig. 310

The machines are particularly adapted to stripping work such as gravel deposits, clay pits, etc., and are used for stripping in coal and iron mines. These machines are mounted on four propelling trucks and temporary tracks are laid for traction.

The prices of the machines, including the services of the manufacturer's superintendent of erection and two men to operate the machine over a period of 25 days when first erected, are $51,750 for the smaller size, $73,300 for the intermediate size, and $105,000 for the largest size.

The small revolving shovels may be mounted on tractor wheels, railroad trucks or caterpillars. They are adapted to stock pile work, cellar excavation, roadway excavation and many other kinds of work. These machines may also be converted for work

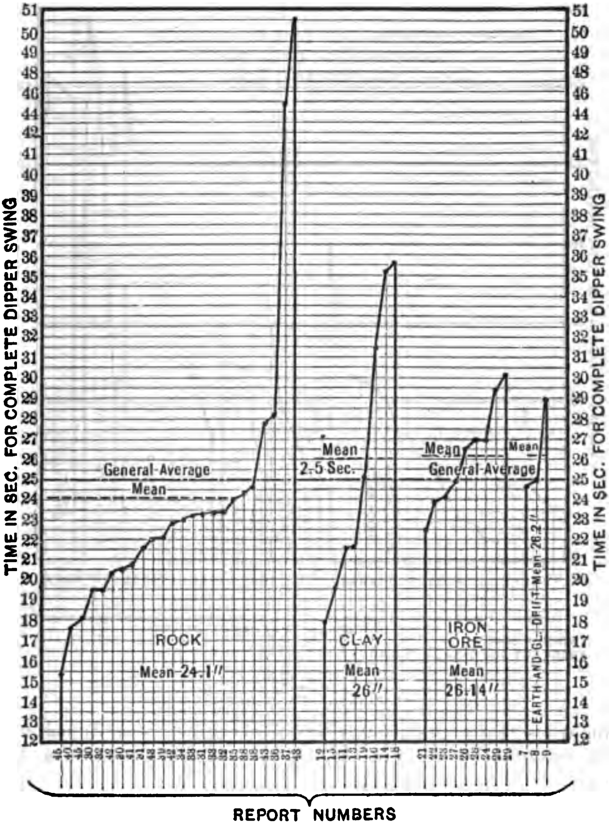


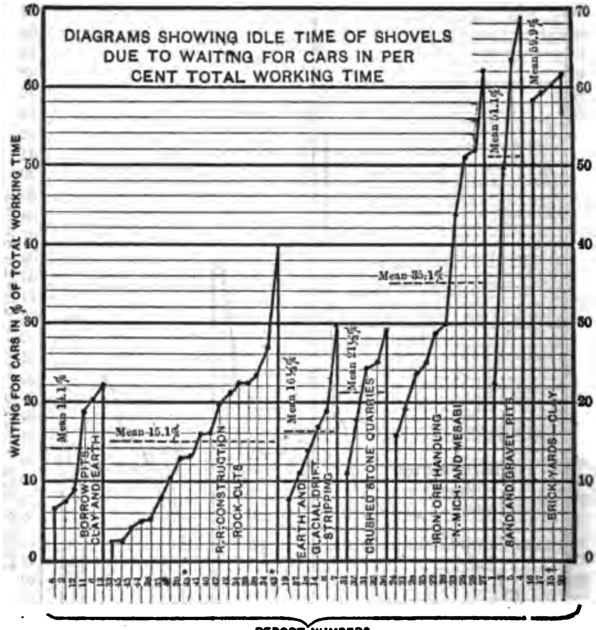
Fig. 311

with a grab bucket, or as a crane. They may be had with extra long boom and handle for work requiring high lifts and reaches.

One manufacturer supplies this type of machine in three standard sizes. The small machine weighs from 21.5 to 27 tons, de-

pending on the type of traction, it has an 18-ft. boom, an 11-ft. dipper handle and swings a ⅔-yd. dipper.

The intermediate size weighs from 28.5 to 34 tons, has a 20-ft. boom and 14-ft. handle and swings a 1-yd. bucket. The largest



†WORK IN SLAG.
*ROCK CUT FOR CANAL WIDENING.

Fig. 312

standard size weighs from 43.25 to 55 tons, is equipped with a 25-ft. boom, a 16-ft. 3-in. dipper handle and operates a 1½-yd. bucket.

The price of these machines, including supervision by the manufacturer when first erected, is as follows:

Weight	Mounting	Price
23.5 tons	Traction	$ 9,000
27	Caterpillar	10,700
31	Traction	13,000
34	Caterpillar	15,100
49	Traction	20,900
55	Caterpillar	24,400

The weights given above are for machines set up with counterweights. The shipping weights are somewhat less as the counterweight is not included in the shipment.

A revolving shovel with a horizontal crowding engine, which enables it to excavate shallow cuts economically, has independent

DIAGRAMS SHOWING ACTUAL SHOVEL WORKING TIME
IN PER CENT OF TOTAL TIME

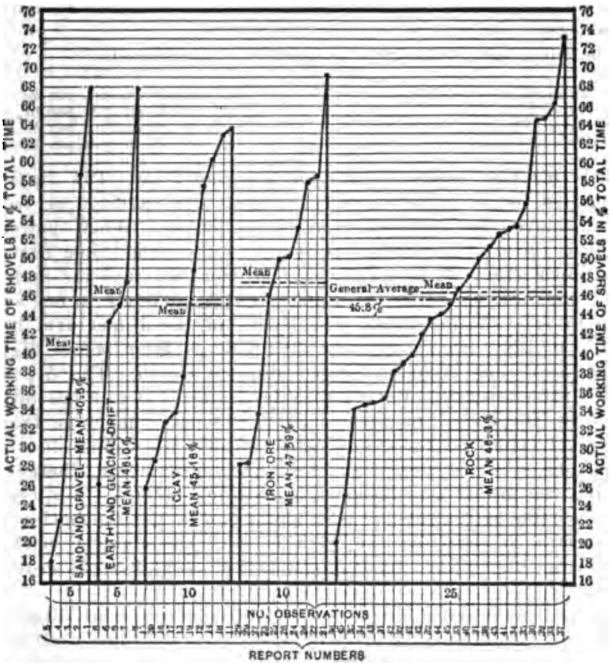


Fig. 313

engines for hoisting, swinging and crowding, and a vertical boiler. They cost as follows:

Type No.	Working wt. in tons	Size dipper cu. yd.	Price f. o. b. Ohio
00	14	½	$ 7,450
0	19	¾	8,650
A1	25	1	10,750
1	32	1¼	13,600

Type 00 and 0 may be had with gasoline power at a cost of about $200 additional.

The above make of shovels is furnished with either shipper shaft or horizontal crowd boom. Types 0 and A1 are also furnished with a combination boom for use with either design of crowding mechanism interchangeably. The gasoline shovels are furnished with horizontal crowd boom.

The shipper shaft boom has an extended working radius, is capable of dumping at great height and can excavate at a depth considerably below the level of the wheels.

The following is the rated capacity of the shovels:

Type 00	30 cu. yd. per hr.
Type 0	45 cu. yd. per hr.
Type A1	60 cu. yd. per hr.
Type 1	75 cu. yd. per hr.

This machine is of the full circle swing type. The dipper is suspended by an adjustable arm hinged to a carriage or trolley which moves horizontally along a trackway. When power is applied, the carriage moves forward at the same time carrying the dipper arm and dipper forward horizontally into the material to be dug, thus enabling the dipper to fill completely in one swing even in very shallow cuts. The length of the dipper arm is adjusted within a range of about 30 in. by a clamp before digging commences thus securing proper digging depth. The depth to which the shovel digs is therefore determined for any one adjustment by the height of the track on which the machine travels. A swivel clamp on the dipper arm permits the dipper to swivel when one side encounters an extra hard obstruction, thereby relieving the dipper and boom from twisting strains. For tearing up macadam pavements or tough material, a prying motion may be exerted by inserting the teeth beneath the material with the trolley in its forward position, and then reversing the crowding motion.

Sewer booms with long dipper handles and special dippers of small size are fitted to shovels for trench work. Clam shell booms for operation of these buckets may be provided and furnished with auxiliary mechanism for derricking boom and handling second rope of clam shell or orange peel bucket. Drag scraper booms can be furnished, with the necessary mechanism for handling the buckets. Counterweighting is necessary. Shovels are commonly operated by steam but may be equipped with electric or compressed air power.

The labor required is as follows: 1 engineer, 1 fireman, in all except very limited outputs, 1 to 2 laborers. The fuel required is from 600 to 1,000 lb. of good bituminous coal per day for type

0 and from 1,000 to 1,500 lb. for type A I, and from 1,500 to 2,000 for type 1. Waste oil, and repairs range from 50 ct. to $2 per day.

A traction steam shovel is made in three sizes as follows:

No. 3 shovel weighs about 10 tons and costs with complete outfit of tools and fittings, but with no scoop or their attachments, $4,750. A skimmer scoop for this machine is 31 in. wide and has a capacity of ½ cu. yd. The price including all attachments is $250. A dipper scoop is 30 in. wide and has a capacity of ½ cu. yd., it costs $160. A set of dipper sticks for the same is $90.

No. 4 shovel weighs about 12 tons and costs, with complete outfit of tools and fittings, but no scoop or attachments, $5,750. Scoops are the same as for the No. 3 machine except the dipper sticks which cost $125.

Clamshell bucket for the No. 3 and 4 machine has a half yd. capacity and costs $650. The attachments for the bucket on the No. 3 machine including extension boom, cables, sheaves and counterbalance, cost $150. Attachments for the No. 4 machine cost $170.

No. 6 shovel weighs about 15 tons and costs with complete outfit of tools and fittings, but without scoops, $6,500. A ¾-yd. skimmer scoop for this machine is 38 in. wide and costs $350 including attachments. A ¾-yd. dipper scoop for this machine is 36 in. wide and costs $250. A set of dipper sticks for the same costs $110. A ¾-yd. clam shell bucket costs $850. Attachment for this bucket costs $200.

Ditcher scoops without attachments cost as follows:

Width of body in inches	Width of cut in inches	Price
16	18 to 20	$115
20	24 to 26	120
24	28 to 30	130
30	34 to 36	145
36	40 to 42	165
42	46 to 48	220

Ditcher scoops most commonly used are the 24 and 30-in. width. Attachments for the No. 3 machine cost $90, for the No. 4 and 5 machine, $100. These attachments consist of boom, beam extension irons, etc.

The application of the scoops is as follows: As a steam shovel using the dipper scoop it will take down and load into wagons a bank about 12 ft. high.

The application of the scoops is as follows: Dipper scoop for regular steam shovel work; Skimmer scoop for grading; Ditcher scoop for ditches and cellar digging; Clam shell for deep ditching

and unloading or loading work. This machine may also be adapted for drag scraper work, particularly backfilling.

Another make of steam shovel that can be equipped with a boom to operate a clam shell bucket costs, f. o. b. Pennsylvania, as follows:

Type	Capacity	Shipping wt.	Price
Steam shovel	½ cu. yd.	24,000	$7,200
Crane	3 ton	24,000	7,200
Steam shovel	¾ cu. yd.	40,000	8,200
Crane	5 ton	40,000	8,200

A Gasoline Shovel with multipedal traction has the following specifications:

Average working speed	1 to 3 dips per min.
Rated capacity per hr., shallow cuts	50 to 60 cu. yd.
Rated capacity per hr., deep cuts	25 to 35 cu. yd.
Approximate shipping weight	35,500 lb.
Price, f. o. b. Chicago, no bucket	$9,500

For digging trenches in ground where it would not be safe to support the shovel on the banks, however well sheeted the trench might be, an arrangement which allows the shovel to dig backward is sometimes used. This consists of an extension boom at the end of and in line with the main boom, but slanting downward at an angle of about 45° to the perpendicular. On the lower end of this are placed the crowding engines, reversed from their usual position, thus pointing the dipper mouth towards the shovel. This allows the shovel to remain ahead of the trench on solid ground.

Where a through cut is being made, the excavation is often too narrow to permit the shovel to turn around and excavate the next cut in an opposite direction, but necessitating the return of the machine backward to the starting point for the next cut. Sometimes this return is 3 or 4 miles long and costs considerable in lost time as well as money. In such a situation the shovel should be equipped with a ball socket, which allows it to be jacked up and revolved on the forward trucks while being held in equilibrium by the weight of the extended bucket and dipper.

Repairs. These depend more on the amount and kind of work done than on the age of the shovel. Repairs are higher for rock work than for earth work, and higher for poorly broken rock than for rock that has been well blasted. Actual total charges for repairs to steam shovels are very difficult to compute, as minor or immediately necessary repairs are made while waiting for trains and during other delays. On most jobs repairs are made at night or on Sundays by the regular crew without extra compensation. Material for repairs to a 65-ton shovel

working in a clay pit for 6½ years amounted to an average of $198.00 per year. The maximum amount per year was $375.00 and the minimum $48.00. This does not include the labor charge. Total boiler repairs during the same period cost $200.00. On a 95-ton shovel in rock excavation the boiler was washed and large repairs made once each week by a special crew. This cost about $32.00 per week. Repairs on a 70-ton shovel working in iron ore were made by the regular crew and cost about 50 ct. a day. During the 6 months ending June 30, 1910, the cost of repairs to steam shovels on the Panama Canal work averaged $27.66 per day per shovel for 9,527 days' service.

Col. Goethals, chief engineer of the Panama Canal, has been kind enough to furnish me with the following information as to steam shovels on that work up to and including the fiscal year 1908. There were then in service 101 shovels, one 20-ton, ten 45-ton, seven 60-ton, thirty-five 70-ton, sixteen 91-ton, and thirty-two 95-ton shovels, which cost a total of $1,094,367.00.

The cost of repairs was as follows:

Fiscal Year Ending	No. of Steam Shovels in Service	Cost of Steam Shovel Repairs	No. of Yards Steam Shovel Excavation	Cost of Steam Shovel Repairs per Cu. Yd.
June 30, 1906	41	$ 20,337.89	1,506,562	$0.0135
June 30, 1907	63	209,244.48	6,215,771	.0337
June 30, 1908	101	479,607.16	17,467,061	.0275
Total	205	$709,607.53	25,189,394	$0.02815

These repairs were accomplished under peculiarly expensive conditions:

1. Wages over 50% higher than in the United States.
2. Cost of privileges granted employes.
3. Unusually difficult excavation.
4. High cost of material.

All steam shovels were given such field repairs as were necessary.

Depreciation. The regular life of a steam shovel is about 20 years, the cost new is about $200.00 per ton and the scrap value about $10.00 per ton. Depreciation per year, by the straight line formula, would therefore be 4.75%.

The size of shovel for any given work should depend upon the

Cubic Yards Excavated per Day in Various Materials with Various Sized Shovels

Size of shovel (tons)	Iron Ore				Sand & Gravel				Earth & Glacial Drift				Rock				Clay				Average			
	No. of shovels observed	Yd. per day Min.	Ave.	Max.	No. of shovels observed	Yd. per day Min.	Ave.	Max.	No. of shovels observed	Yd. per day Min.	Ave.	Max.	No. of shovels observed	Yd. per day Min.	Ave.	Max.	No. of shovels observed	Yd. per day Min.	Ave.	Max.	No. of shovels observed	Yd. per day Min.	Ave.	Max.
45	..	....	....	....	2	360	366	373	..	....	....	....	..	...	...	....	..	...	...	...	2	360	366	373
55	..	....	....	....	..	....	....	....	..	....	....	....	..	...	...	....	1	320	320	320	1	320	320	320
65	..	....	....	....	..	....	....	....	1	1,065	1,065	1,065	5	264	601	896	2	474	627	780	8	264	665	1,065
70	7	892	1,095	1,512	3	1,602	2,365	3,300	3	569	893	1,426	16	168	682	1,542	5	498	1,064	1,450	34	168	991	3,300
75	..	....	....	....	..	....	....	....	..	....	....	....	..	...	...	....	1	820	820	820	1	820	820	820
90	1	2,728	2,728	2,728	..	....	....	....	..	....	....	....	..	...	...	....	..	...	....	....	1	2,728	2,728	2,728
95	1	1,350	1,350	1,350	..	....	....	....	1	1,073	1,073	1,073	5	154	873	1,200	1	990	990	990	8	154	972	1,350
Avge.	9	892	1,305	2,728	5	360	1,566	3,300	5	569	963	1,426	26	154	704	1,542	10	320	870	1,450	55	168	934	3,300

yardage in each cut, not upon the total yardage of the contract. It depends also upon the distance and the character of the ground over which the shovel has to be moved and the number of moves to be made. Use a 26-ton shovel for small cuts where moves will be frequent, a 55 to 65-ton where cuts are heavy and moves not frequent, and the largest available one where the cuts are very long and deep.

The cost of moving a shovel varies greatly with the conditions. In certain railroad excavation it took 4 weeks with a full crew to move a 65-ton shovel 6 miles, and 3 weeks to move down across a valley from the finished cut to a new cut, a distance of ¼ mile. The cost of moving a 65-ton shovel 1 mile on a country road with heavy grades, and ½ mile through fields with a 15° slope, was $316. It took 8 days, involving the services of 1 shovel crew, 1 team, 1 foreman, and 8 men. A 35-ton traction shovel has been moved 18 miles in 18 days by its crew, whose wages amounted to $35 per day, 17 miles being over rough roads and 1 mile being across fields and up hill.

Cost of Moving a Steam Shovel. The following is from *Contracting*, August, 1916.

Moving a steam shovel from one job to another involves a great deal more expense than many people would expect and is likely to make an important addition to the overhead charges of this kind of plant, especially when used on small jobs. A 60-ton Marion steam shovel was recently shipped 32 miles by rail and motor truck and reinstalled at a total cost of $1,186, while another move of 22 miles by railroad and 17 miles under its own power cost $3,974. Although the first operation involved an expense of nearly $400 for completely dismantling and reassembling the shovel, it saved a considerable percentage of the transportation charges at the expense possibly of some delay, since the shovel was out of service for 61 days as compared with 49 days for the railroad transfer. It is possible that a system of auxiliary wheels to distribute the load over a larger area of roads and bridges in transit, if it could be satisfactorily applied, together with a higher-geared propelling mechanism, would save considerable time and expense and the dismantling be avoided.

Power Consumption of Electric Shovel

An electric shovel with a 2½-cubic-yard dipper was used in excavating gravel for the Carson River dam at Lahontan, Nev. The line voltage was 2,300, which was stepped down to 440 by three 90 K. V. A. single-phase transformers located on the shovel. These transformers were connected to the distributing system by

700 ft. of triple-covered flexible cable armored with D-shaped steel tape, which was dragged along the ground as the shovel moved. This cable was dragged over rocks and through mud and water, but required very little protection. The hoisting machinery was driven by a 115-hp., 440-volt, three phase, 60-cycle, variable-speed induction motor. The propelling machinery was also driven by this motor. The swinging machinery was geared to a 50-hp. motor, and the thrust motor was also 50-hp. The compressor which furnished air to the hoisting drum brake, the emergency brake on the swing motor, and the friction clutch and brake on the intermediate shaft were driven by a 2-hp. constant speed induction motor.

A test made on October 14, 1912, when the shovel was working in a gravel bank 10 to 12 ft. high, with a clear lift of dipper of 16 ft., loading 6-car trains, gave the following results:

Total time observed, 45.5 minutes.

Digging and loading occupied 57% of the time. Delays, moving up, etc., occupied 43% of the time. Rate of digging on observed basis, 1,500 cubic yards of loose gravel in 8 hours. Total power consumed by shovel in 8 hours, 453 kw. hours — 0.302 kw. hours per cubic yard of loose gravel.

Railroad Grading with an Electric Shovel.* The following is from the *Excavating Engineer*, Jan., 1915.

The Wilkes-Barre Railway Co. have been operating a Bucyrus 14-B, revolving, railway truck mounted, ⅝-yd. dipper shovel. This machine was operated by electric current at 575 volts D C, and has variable speed motors of the following size: Hoist motor, 30 hp.; swing and thrust motors each 15 hp. The working weight of the shovel is 19 tons.

A 3500-cu. yd. slide was handled between April 19 and May 8, 1914. The material was hardpan, loosened by frost, and containing gravel and small boulders up to 2 or 3 cu. ft. in volume. This material was wet and weighed 125 lb. per cu. ft. The shovel loaded into 10-yd. steel Western side air-dump cars; two cars and two motors were used. One motor conveyed the loaded car to a switch 800 ft. distant and returned with the empty car; the other motors hauled the cars between the switch and the dump, an average distance of a mile. Much delay was caused by the distance between the shovel and switch and the resulting enforced idleness of the machine while waiting for cars. On a typical day the shovel was in operation 225 minutes out of 600 working minutes.

* Electric shovel operation on an electric railway; the Wilkes-Barre Railway Company have been operating an electric revolving shovel on their lines for the past year with splendid results. Some records of performance with cost figures. *The Excavating Engineer*, January, 1915.

The material was dumped along the side slopes of existing fills and probably not more than 20% was spread by hand, yet the cost of spreading amounted to nearly 50% of the labor cost. It is worth noting that a thin layer of ashes spread on the steel bottom of the cars before loading greatly facilitated the dumping of this sticky material.

COST OF REMOVING 3500-CU. YD. SLIDE

Labor	Ct. per cu. yd.
Excavating and loading	2.1
Spotting cars	1.3
Hauling and dumping	1.8
Spreading on dump	4.0
Total labor	9.2
Including supervision, about	10.0
Power	
160 kw.-hr. per day (estimated) at 1.5 ct. equals $2.40 per day	0.75
Motor car, 175 kw.-hr. per day	0.80
Total power	1.55
Repairs, supplies, estimated at $2 per day	0.60
Total cost per cu. yd.	12.15

No allowance for interest or depreciation.

A side cut, 800 ft. long, and from 1 to 6 ft., averaging 3.5 ft. deep, on the center line, containing 2,450 cu. yd., was graded in 12 working days. One motor car and one 10-yd dump car were used for hauling the material over a very steep and poorly aligned track to the fill. Much delay was caused by the lack of power to drive the motor. The material was generally loam but about 25% was shale varying from easy to hard digging. The fill was 600 ft. long and 2 to 8 (average 5) ft. deep. 200 ft. of crib trestle were erected on the deeper portion of the fill. The cost is given as follows:

COST OF GRADING A 2450-CU. YD. SIDE CUT

Labor	Total cost	Cost per cu. yd.
Grading for temporary track	$ 50.00	$0.0204
Moving shovel into position	13.24	0.0054
Excavating and loading material	107.74	0.0438
Hauling and dumping	60.74	0.0247
Building crib trestle	25.00	0.0102
Spreading and jacking track	134.20	0.0547
Watchman (two-thirds time)	12.80	0.0052
Blacksmith	5.90	0.0024
Throwing track to permanent position	30.00	0.0122
Total	$439.62	$0.1790
Supervision	43.96	0.0179
Total	$483.58	$0.1969

Power		
Shovel, 1260 kw.-hr. at 1.5 ct.	$ 18.90	$0.0088
Hauling, 480 kw.-hr. at 1.5 ct.	7.20	0.0029
Total	$509.68	$0.2086

Comparative Operating Costs of Steam and Electric Shovels. The following is taken from a paper by H. W. Rogers in the Feb., 1914, *Bulletin of the American Institute of Mining Engineers.*

Consider a 120-ton shovel which is ordinarily equipped with a 5-cu.-yd. dipper and has an average capacity of approximately 2,500 cu. yd. per 10-hour day. This capacity is based on an average working time of 55% and an average dipper capacity of 3¾ cu. yd. in 75%. With a good grade of coal the steam shovel will require approximately 3¼ tons per 8-hour shift and will make an average of two complete cycles per minute. For the purpose of comparison, however, the maximum capacity of the shovel is taken; i. e., three cycles per minute. Under these conditions either the steam or the electric shovel will have a total working time during one shift of $8 \times 60 \times 0.55 = 264$ min. during which time it will make $264 \times 3 = 792$ complete cycles, and will handle $792 \times 3\frac{3}{4} = 2{,}970$ cu. yd. of material.

The direct-current shovel would be equipped with two 80-hp. 500-r.p.m., 230-volt series motors on the hoist, one 40-hp., 550 r.p.m., 230-volt series motor on the swing, one 60-hp., 550 r.p.m., 230-volt series motor on the thrust, and one 150-kw., 900 r.p.m., 250-volt direct-current generator direct connected to a 225-hp., 900 r.p.m., 2,200-volt induction motor, with four-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw.-sec.
Hoisting	1,379
Swinging	522
Crowding	547
Total	2,448 = 0.68 kw.-hr.

Now $792 \times 0.68 = 539$ kw.-hr. input to the motors per 8-hour shift, or, taking into account the efficiency of the motor-generator set, 657 kw.-hr. per 8-hour shift.

As the shovel is working only 55% of the time, the motor-generator set will be running light 45% of the time, or $8 \times 60 \times 0.45 = 216$ minutes.

The power consumption on the set when running light will be approximately 16.77 kw. $\frac{216 \times 16.77}{60} = 60.4$ kw.-hr. loss per 8-hr. shift.

$657 + 60.4 = 717.4$ kw.-hr. total power consumption per 8-hour shift when working under the maximum cycle.

$$\frac{717.4}{2,970} = 0.241 \text{ kw.-hr. per cubic yard excavated.}$$

The alternating-current shovel would be equipped with two 150-hp., 450 r.p.m., 440-volt motors on the hoist, one 50-hp., 720 r.p.m., 440-volt motor on the swing, one 75-hp., 600 r.p.m., 440-volt motor on the thrust, and three 125 kilovolt-ampere, 2,220-480-volt transformers, with five-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw.-sec.	
Hoisting	2,040	
Swinging	759	
Crowding	750	
Total	3,549	= 0.987 kw.-hr.

Now $792 \times 0.987 = 782$ kw.-hr. input to the motors per 8-hour shift or, taking into account the efficiency of the transformers, 796 kw.-hr. per 8-hour shift.

The no-load losses on the transformers will be approximately $\frac{216 \times 3.6}{60} = 13.0$ kw.-hr. loss per 8-hour shift. $796 + 13 = 809.0$ kw.-hr. total per 8-hour shift $\frac{809}{2,970} = 0.273$ kw.-hr. per cubic yard excavated.

Labor per shift —	Steam	Electric
Shovel runner	$ 6.00	$ 6.00
Craneman	4.00	4.00
Fireman	2.50	....
Six pitmen at $1.75	10.50	10.50
One watchman	1.75	....
One coal passer	1.50	....
Teaming (½ day)	2.50	....
Oil and waste	1.50	0.75
Total	$30.25	$21.25
Saving, electric over steam	21.25	
Per shift	$ 9.00	

For convenience in comparing the costs of operation on steam and electric shovels the costs are all reduced to a day basis.

	Steam	Electric: Direct current	Electric: Equivalent alternating current
Interest at 6%	$ 5.20	$ 7.75	$10.85
Depreciation at 4⅔%	4.03	6.00	8.43
Repairs at 10%	8.66	...	...
Repairs at 6%	...	7.75	10.85
Labor, per shift	30.25	21.25	21.25
Total cost per shift	$48.14	$42.75	$51.38

It has been assumed that, owing to weather conditions, delays, etc., the shovel working year consists of 150 days and the above figures are based on this assumption; also that the shovel is only working one shift a day.

If the shovel works three shifts a day instead of one shift a day, the interest and depreciation will remain the same, provided the shovel is kept in repair. It is reasonable to assume that the repairs will increase when working three shifts, but not in direct proportion; therefore this item has been increased 50%.

	Steam	Direct current	Equivalent alternating current
Interest at 6%	$ 5.20	$ 7.75	$10.85
Depreciation at 4⅔%	4.03	6.00	8.43
Repairs at 15%	13.00	...	...
Repairs at 9%	....	11.63	16.28
Labor (three shifts)	90.75	63.75	63.75
Total cost (3 shifts)	$112.98	$89.13	$99.31

Disregarding the cost of coal and electric power, the saving of the direct current shovel over the steam shovel would be $810 per year for one shift operation and $3,580 per year for three shifts.

The alternating current shovel when working one shift a day would show a loss of $486 per year. On the other hand, if this shovel worked three shifts per day it would show a saving of $2,050.50 per year. Any greater saving than that shown, would depend upon the comparative cost of coal and electric power, but as this is a variable it could only be shown by means of a curve.

Method of Erecting a Standard Shovel. The following ingenious suggestion by Mr. G. W. Williams appeared in the *Excavating Engineer.*

It is sometimes quite a task to erect a standard railroad type shovel when labor is scarce, as there are a number of heavy pieces to be handled. To facilitate this work, a very handy and efficient jib crane can be constructed, as shown in the accompanying sketch, by attaching a piece of 8-in. x 8-in. x 10-ft. timber to the A-frame collar, which will act as a center pintle, so

that the timber can be swung around in any position. Attach chain falls or block and tackle at any convenient point on the timber jib and heavy parts such as jack arms, sheaves, chains, etc., can be handled with ease. Parts can be lifted from the idler car and placed in position alongside the shovel and jack arms put in place on the shovel without any trouble.

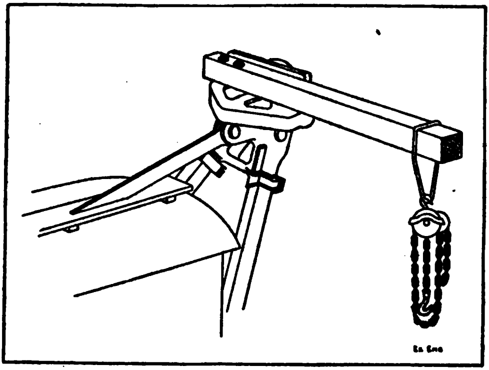


Fig. 314.

To get the timber up on the roof of the shovel and attach it to the A-frame collar is a comparatively simple matter. Fasten two ropes to the running board on the roof. Drop the bight of both lines to the ground and place the timber in them. Two men on the roof can easily roll it up. Swing the A Frame collar parallel to the shovel and place one end of the timber on it, supporting the other end on the roof of the shovel by blocking of the proper height. Bolt the timber securely to the collar and you will have a very simple and practical crane. A piece of T-rail can be used if a timber is not available.

Derrick Excavators

Cap. in cu. yd.	Size of Boom Standard Carriage is built for inches	Wt. of carriage, lb.	Wt. of shovel, lb.	Avge. length of boom ft.	Avge. length of mast, ft.	Hoisting engine, cylinder double drum and swing gear: Cylinder	Hoisting engine, cylinder double drum and swing gear: Boiler, hp.	Plow steel gripping cable, diam.
½	12x12 and 12x14	925	1875	30–60	35–65	7 x10	20	1 inch
⅝	14x14 and 14x16	975	2000	35–55	40–60	7 x10	30	1 inch
⅞	14x14 reinforced and 14x16	1050	2845	35–50	40–65	8¼x10	30	1 inch
	14x16 and 14x18	1125	3200	35–50	40–65	8¼x10	30	1 inch

I have found this to be a great labor and time saver and easily rigged up.

A recent addition to the large number of excavators is the Union Derrick Excavator.

The properties of this machine furnished by the manufacturer are as follows:

Carriages can be made for any size of booms, other than specified above.

The length of dipper stick is governed by the depth of digging; if digging is to be done at a considerable depth below base of derrick, the dipper stick must be lengthened accordingly.

The changing of the carriage, for example, from a 12 x 12 to a 12 x 14 boom, or vice versa, is accomplished by simply shifting two angles held by a number of bolts.

The price of the above, f. o. b. New York, including carriage with all attachments ready to be fitted to the boom of a derrick, manganese steel teeth, and gripping cable, but not including wooden dipper arm, are as follows:

3/8 cu. yd. capacity	$ 650
1/2 cu. yd. capacity	850
5/8 cu. yd. capacity	950
7/8 cu. yd. capacity	1,050
1 cu. yd. capacity	1,150

SECTION 90

SKIPS

Stone Skips similar to Fig. 315 are built of heavy steel plates and reinforcing bars. The ¾-yd. size is designed for handling

Fig. 315. Stone Skip.

excavation, brick and mortar on lighter foundation work. The other sizes are proper for heavy work on bridges, dams, etc.

Capacity cu. yd.	tons	Dimensions in feet	Weight complete in lb.	Price f. o. b. factory
¾	1½	4 by 5 by 1	455	$120
1	2	5 by 6 by 1	667	135
1½	3	5 by 6 by 1½	805	170
2	4	6 by 6 by 1½	1082	205

Cableway Skips constructed of heavy steel plates with reinforcing and hanger bars, used in the construction of dams, reservoirs and other large work, cost as follows:

Capacity in tons	Dimensions in feet	Weight complete in lb.	Price f. o. b. factory
3	5 by 6 by 2	1300	$210
4	6 by 6 by 2	1490	235
5	7 by 7 by 2½	2575	310
8	8 by 8 by 2½	3530	410

SECTION 91

SLEDGES AND HAMMERS

Sledges. Blacksmith's cross pein 5 to 24 lb., double face 5 to 24 lb., striking and drilling hammers 3 to 14 lb., stone sledges 10 to 24 lb., cost approximately 30 cents per lb. for 5 lb. and over, and 40 cents per lb. for under 5 lb. Handles cost about $2.50 per doz.

Hammers. Bricklayer's hammers, without handle, cost as follows:

Weight lb. oz.	Price per doz. Plain eye	Adze eye
1—2	$11	$12
1—8	12	13
2—	13	14
2—8	14	15

Nail hammers cost as follows:

Weight lb. oz.	Per doz.
1—12	$12.00
1—4	9.00
1—	8.50
—13	8.00
—7	7.50

Riveting hammers (plain eye) cost as follows:

Weight lb. oz.	Per doz.
—4	$5.50
—7	5.70
—9	6.00
—12	6.25
—15	6.50
1—2	7.00
1—6	7.50
1—10	8.00

SECTION 92

SPRINKLERS

Sprinkling Cars and Wagons, Oil Distributors and Tank Wagons.

A sprinkler furnished with either platform spring gears or reach gears is made in the following sizes:

Capacity in gal.	Weight in lb.	Price f. o. b. factory
450	3100	$800
500	3200	825
600	3400	850
750	3650	900
1000	3900	975

Road Oiling Machinery. A pressure road oiler of 600 gal. capacity, the standard equipment of which applies up to one-third gallon per square yard in an eight foot width, is operated by one man. It will handle all grades of oils or tars for dust laying or road rebuilding operations, and is furnished either with or without a heating attachment. The approximate weight of this machine is 4,090 lb., and it costs $1,000 f. o. b. Chicago. A heating attachment for it consists of a jacket around the tank proper, the heat being supplied by a gasoline or kerosene burner. The approximate weight of the machine with the heating attachment is 4,700 lb., and the price is $1,100.

A pressure distributor for applying light oils and tar products under pressure consists of a steel tank, equipped with heating and distributing devices, mounted on a platform spring gear truck. The capacity of the tank is 600 gal. The heating device consists of a fire box designed to burn wood or oil. The amount of material applied can be regulated from one-tenth to four-tenths of a gal. per sq. yd., and can be applied at a pressure of from 5 to 25 lb. per sq. in. The machine weighs 3,400 lb. empty, complete, and costs $1,000 f. o. b. factory.

A heating distributor similar to the above, except that the pump is larger and that it is fitted with a kerosene burner, for heating the oil, weighs empty, complete, 4,400 lb., and costs $1,250 f. o. b. factory.

A distributor for applying heavy bituminous binders under pressure consisting of an air tight asphalt drum, equipped with two sets of distributing valves and nozzles, an air reservoir and air compressor all mounted on a heavy frame, which in turn is

Fig. 316.

supported on four broad rolls, has a capacity of 200 gal. It is ordinarily drawn by a road roller. This machine weighs complete, empty, 4,100 lb., and costs $1,000 f. o. b. factory.

SECTION 93

STONE BOATS

Mr. H. P. Gillette says: "A team of horses can exert a pull of 1,000 lb. for a short time if they have a good earth foothold. The sliding friction of iron or wood on earth is about 50% of the weight of the load that is being dragged, hence a team is capable of dragging a stone boat and load together weighing 2,000 lbs." If a "skid road" of partly buried timber is built and kept well greased a stone boat can be hauled with extreme ease. A weight heavier than a wagon load can be pulled. Stone boats 3′ wide, 7′ long with three 4″ x 4″ timber runners curved up in front and shod with iron, and a 2″ plank floor have been made on jobs in the vicinity of New York from 1907 to 1910 costing $15 to $20. They last about one season under hard work with one reshoeing which costs 50% of the original cost.

SECTION 94

STUMP PULLERS

There are four methods of grubbing: By hand, by burning, by blasting, and with a stump pulling machine. An axe, a mattock, a round pointed shovel, and a long heavy pole for use as a lever are the tools required in the first method. If trenches are dug around the stumps in the fall of the year, the frost will aid materially in heaving the stumps.

On land that has been cut over previously, leaving the stumps wholly or partially dead, burning is sometimes economical. Where the stumps are green, they must be removed from the ground and dried before they will burn.

By far the best method of grubbing is by blasting, if properly done. A ship auger 1 or 1¼ inches in diameter, costing $1 to $1.25 should be used to bore a hole near the base of the stump.

For small stumps dynamite should be used exclusively. The

hole in large stumps should first be sprung with a small charge of dynamite, and then blown with Judson or black powder.

Mrs. Edith Loring Fullerton in "The Lure of the Land" gives the following account of means used in grubbing and clearing the land of the Long Island Experimental Farm. "Small stumps up to four feet require about ½ lb., while large ones, say, six to eight feet in diameter, require 3 lb. of the explosive which is placed in several separate holes surrounding the stump. . . .

"Fourteen fuse charges are placed under as many stumps; the method of placing, by the way, is to lower the charge into the oblique hole, press it steadily and firmly with a blunt ended stick until expanded to the full size of the crowbar hole, then fill up the hole with earth and tramp it firmly, that no explosive gases may find a loophole of escape. . . .

"Dynamiter Kissam, with 'Dell' Hawkins' assistance, blew regularly from 75 to 110 stumps a day. The dynamite splits them so completely that they can be burned at once. The stumps taken out by hand required cleaning, splitting and drying before they could be burned; an added expense. Below are the comparative figures on 100 stumps (about 1910):

DYNAMITE.

Average 60 lb. dynamite at 15 ct. per lb.	$ 9.00
Labor of expert and helper	5.50
100 fuses at 45 ct. per 100 ft.	.75
100 caps at 75 ct. per 100	.75
Total	$16.00

HAND LABOR.

100 average stumps require 3 men 33 days at $1.33 per day, $131.67

"Stump pullers were out of the question, there was no standing timber for the block and fall to be fastened to, the time necessary to hitch to stumps buried just under the surface, frequently with rotted heart, together with the cost of the puller, hire of horses and men, made it way beyond the power of competing with dynamite."

For further data on this subject, the reader is referred to the excellent little book: "Clearing aand Grubbing," by H. P. Gillette.

Cost of Clearing Cut Over Land with Power. The following is from *Engineering and Contracting,* Dec. 19,1917.

The site selected for the operations was on level bottom land in the valley of the Palouse River, Idaho. The soil is classified by the U. S. Bureau of Soils as "potlatch silty clay loam with a tendency to be clayey." The soil was underlaid with a hard-

pan formation at an average depth of about 3½ ft. It had been covered formerly with a dense stand of western yellow pine, Douglas fir and western larch, in approximately equal proportions as shown in the following table:

PERCENTAGE OF TIMBER.

Plot No.	(Ft. dia.) Red fir	Yellow pine	Tamarack
1	35.7	30.5	34.7
2	49.3	23	27.7

Some of the pine had been cut 8 years. Most of the tamarack and fir had been logged more recently; some only 2 years before. All except the smaller stumps were sound.

Two working plots each of 5 acres were carefully selected with the view of securing representative cost figures. Each plot was handled in exactly the same manner as regards preliminary work, the making of holes, piling and burning logs, brush and stumps, and leveling the ground after all clearing work had been done. The explosive used in Plot No. 1 was a 20% stumping powder; on Plot No. 2 a potassium chlorate powder equivalent to 60% dynamite was employed.

The number and per cent. of sound stumps in each plot were as follows:

NUMBER AND PER CENT. OF SOUND STUMPS.

Diameter	Plot No. 1 Ft. dia.	Plot No. 1 %	Plot No. 2 Ft. dia.	Plot No. 2 %
6-in.	26	5	4	1
8-in.	12.8	2.4	7.8	1.7
10-in.	19.1	3.7	12.5	2.8
12-in.	3.1	6	2.0	4.7
14-in.	22.2	4.2	11.8	2.7
16-in.	38.8	7.1	40	9
18-in.	28.5	5.4	28.5	6.4
20-in.	48.4	9	26.6	6
22-in.	57	11	55	12
24-in.	46	8.4	24	5.4
26-in.	39	7.3	32.5	8
28-in.	30.4	5.7	21	4.8
30-in.	12.5	2.3	17.5	4
32-in.	21.4	4	26.7	6
34-in.	14.1	2.6	21.6	4.8
36-in.	24	4.5	15	3.4
38-in.	12.6	2.3	12.6	2.8
40-in.	6.7	1.2	6.7	1.5
42-in.	10.5	2	14	3.1
44-in.	18.3	3.4	29.3	6.6
48-in.	8	1.5	8	1.8
56-in.	4.6	0.7	9.3	2.1

A crew of from 4 to 6 men was used for the work of swamping and sawing, while two men with teams worked to best advantage after the material was cut up and rolled out where it was easily

accessible. The large logs were thrown into heaps and constituted the base of all the piles. The lighter logs with limbs, brush and stump fragments were then thrown on top, completing the work preparatory to burning. The tools used were the axe, the cross-cut saw, cant-hooks, mattocks, shovels, augers, block and tackle, ⅝-in. wire cable, a snatch block open at the side to admit cable without passing the end through the block (a very great advantage), and a digger with a 3-in. cylindrical bit open on one side and welded to an 8-ft. handle of 1-in. gas pipe, which is an excellent tool, capable of cutting its way through roots and frozen ground. A battery costing about $18 with lead wires completed the outfit of tools.

The preliminary work consisted of swamping and sawing and placing all brush and unsound logs, limbs, brush, etc., in piles for burning. The cost of the preliminary work was as follows:

	Plot No. 1			Plot No. 2		
	Hours	Rate	Total	Hours	Rate	Total
Swampers	176	$0.25	$44.00	143	$0.25	$33.75
Sawyers	39	.25	9.75	44	.25	11.00
Teamsters	40	.25	10.00	19	.25	4.75
Teams	40	1.00*	4.45	19	1.00*	2.10
Feed	..	1.00*	4.45	..	1.00*	2.10
Total			$72.65			$73.70
Per acre			14.53			14.74

* Per day.

The cost of making the holes for the powder was as follows:

	Plot No. 1			Plot No. 2		
	Hours	Rate	Total	Hours	Rate	Total
Boring holes	152	$0.25	$38.90	168	$0.25	$42.00
Per acre			7.78			8.40

The labor cost of the blasting was as follows:

	Plot No. 1			Plot No. 2		
	Hours	Rate	Total	Hours	Rate	Total
Powderman	58	$0.35	$20.20	41	$0.35	$14.35
Helper	58	.25	14.50	68	.25	17.00
Total			$34.70			$31.35
Per acre			6.94			6.27

The cost of piling the stumps was as follows:

	Plot No. 1			Plot No. 2		
	Hours	Rate	Total	Hours	Rate	Total
Swampers	168	$0.25	$42.00	220	$0.25	$55.00
Teamsters	42	.25	10.50	52	.25	13.00
Teams	42	1.00*	4.65	52	1.00*	5.80
Feed	..	1.00*	4.65	..	1.00*	5.80
Total			$61.80			$79.60
Per acre			12.35			15.92

* Per day.

The estimated cost of leveling the ground per plot was as follows:

	Hours	Rate	Total
Teamsters	20	$0.25	$ 5.00
Helpers	20	.25	5.00
Teams	20	1.00*	2.00
Feed	..	1.00*	2.00
Total			$14.00
Per acre			2.80

* Per day.

The estimated cost of burning per plot was: One man 80 hours at 25 ct. or $20, making the cost per acre $4. The average amount of powder used for each size of stump is shown in Table I.

General figures on the clearing of the two plots follow:

	Plot No. 1	Plot No. 2
Area, acres	5	5
Number of stumps	479	365
Total feet diameter	703.3	674.7
Average diameter, in.	14.4	21.2
Powder used, lb.	1,678	2,000
Cost powder, ct. per lb.	16	17
Cost powder per ft. diameter, ct.	39.3	50
Blasting holes, ft.	1,220	1,228
Cost blasting per ft. hole, ct.	.032	.034
Blasting caps, No. 5, number	297	6
Electric fuses, No. 6, number	340	595
Triple tape fuse, ft.	422	9

The final cost figures were as follows:

	Total cost		Per acre		Cents Per ft. dia.	
	Plot No. 1	Plot No. 2	Plot No. 1	Plot No. 2	Plot No. 1	Plot No. 2
Prelim. work	$ 72.65	$ 73.70	$ 14.53	$ 14.74	10.3	10.4
Making holes	38.90	42.00	7.78	8.40	5.5	6.2
Blasting	34.70	31.35	6.94	6.27	4.8	4.6
Powder	276.50	340.00	55.30	68.00	39.2	50.4
Caps	24.77	38.73	4.95	7.74	3.5	5.7
Fuse	4.22	0.09	0.84	0.02	0.6	0.0
Piling stumps	61.80	73.80	12.36	14.76	8.8	10.8
Burning	20.00	20.00	4.00	4.00	2.8	3.0
Leveling	14.00	14.00	2.80	2.80	2.0	2.1
Total	$547.54	$633.67	$109.50	$126.73	77.5	93.7

Land Clearing with Donkey and Traction Engines. Information on the clearing of land with donkey and traction engines is given by Mr. C. H. Shattuck in Bulletin No. 1, "Method of Clearing Logged-Off Land," published by the University of Idaho.

The donkey engine, the caterpillar, or the ordinary traction engine used in threshing may each be operated to advantage on stumps of various sizes, depending on the power of the engine

used. The 60-hp. donkey engine, states Mr. Shattuck, will pul practically any sound stump up to 30 in. in diameter and almos any cracked stump. It will also clear from 3 to 5 acres a one setting and pile the same. An efficient crew can pull, pile and burn the stumps remaining where heavy cedar, fir, white pine and tamarack timber has been removed at from $75 to $115 pe acre, the cost being distributed as follows:

Preliminary work	$25 to $ 40.00
Pulling	30 to 50 00
Burning	10 to 12.50
Leveling	10 to 12.50
	$75 to $115.00

The above figures are from actual clearing operations on a farm at Samuels, Ida., and represent the best that can be ex pected from this method for such timber, as the machinery an men were all that one could desire from the standpoint o efficiency. The timber was as heavy as is generally found The trees probably averaged 80 to the acre and 30 in. in diame ter, and were mostly sound. Open yellow pine land and tha containing small timber can be cleared for very much less. The cost of burning and leveling is considerably increased by failure to remove all the earth possible from the stumps before piling and also by making the piles too large. After the larger piles (where a gin pole is used) have burned for some time, the earth falling from the roots of the upper stumps smothers the fire leaving many unconsumed stumps and fragments buried under masses of earth which must be removed and the fragments repiled and fired a second time. Large hummocks of earth aver aging 30 x 30 x 4 or 5 ft. and containing from 3,000 to 5,00 cu. ft. of badly burned earth resembling fire brick are thus left to be distributed over the fields at considerable expense and more or less to the detriment of the soil.

The Holt caterpillar 60-hp. engine, states Mr. Shattuck, will remove sound stumps up to 18 or 20 in., and the caterpillar features give it a very decided advantage in getting over uneven or swampy ground. It also works rapidly and is very efficient for small stumps and young standing timber. It has been known to pull 100 stumps per hour for 7½ hours on a speed test, and has also averaged 450 stumps per day at regular land clearing work.

The ordinary traction engine used in threshing, wood-sawing, etc., can be so rigged as to pull small stumps and young trees much as described for the caterpillar. This machine works well on sound stumps under 12 in. and on well cracked stumps or

on small timber. These machines are not so easily handled on rough or swamp ground, nor are they as fast as the caterpillar engine, but many more of them are available.

Cost of Pulling Small Trees with a Traction Engine. The following appeared in *Engineering and Contracting*, May 7, 1913:

A field of about 60 acres was covered with a scattering growth of small trees, varying from saplings 1 in. in diameter to young trees having a diameter of 7 or 8 in.

The owners of the land had a gasoline-kerosene traction engine of 45 bhp., and with this pulled the saplings out bodily, without the aid of falls or snatch blocks. A ⅝-in. Norway iron chain 30 ft. long was used. One end of this chain was attached to the draw bar of the engine by means of a clevis, and the other end was given one and one-half turns around the tree to be pulled, and the end of the chain made fast with a grab hook. The first trees attempted were about 3 in. in diameter, of persimmon, elm and black jack, all well rooted. Taken one at a time, they pulled out without great difficulty. Pulling two trees with one hitch by taking two turns of the chain about the first tree and leading the chain back to a second proved feasible, and the plan was extended as experience was gained to as many hitches as were permitted by the length of chain available, when the trees were not too large.

For the larger trees, 4 to 8 in., a single pull to each tree was taken, the hitch as high above the ground as practicable; and a block of wood, 8 or 10 in. in diameter by 4 ft. long, was thrown on the ground against the tree and directly under and at right angles to the chain. This bearing acted as a fulcrum when the tree was bent over by the pull, and served to bring a very powerful pull on the roots remote from the engine. In the case of a few 8-in. black locusts, a man stood by the tree with an axe and struck off the roots remote from the engine as the pull indicated their location. This process materially assisted. It was found that the most satisfactory results were secured with the larger trees when the hitch was made at a height of from 3 to 5 ft. above the ground.

The engine, as stated above, was a gasoline-kerosene engine having four vertical cylinders and rated at 45 bhp. The engine ran continuously, and the power was transmitted through an efficient friction clutch. The engine was reversible and could be reversed from forward to backward motion in 5 seconds. This feature was of value in providing slack in the chain immediately after a pull, and in backing down for the next hitch.

It was found necessary to use the full length of the 30-ft. chain in pulling the trees 4 in. in diameter and over, as the tops

often came down directly towards the engine with a vicious crash. The most efficient procedure was found to consist in running the engine at full speed and to bring the tractor against the load slowly until the pulling chain became taut, then suddenly to bring the full power of the engine against the pull by means of the friction clutch.

Owing to the intermittent character of the loading it was found impossible to obtain satisfactory results with any fuel but gasoline. The fuel consumption was quite low for the reason that very little was consumed except at such times as the tractor was actually making a pull.

The following is a statement of the expense attending the cleaning up of this field, careful count being kept of every tree pulled. Everything smaller than about 3 in. was cut down with the axe, but there were not a great number of these and they are not included in this statement.

COST OF PULLING 1,246 SMALL TREES, 3 IN. TO 8 IN. IN DIAMETER.

108 gal. gasoline at 14 ct.	$15.11
Lubricants	2.32
One engine man 4 days at $3	12.00
Two laborers 4 days at $1.75	14.00
Charge for use of engine 4 days at $5	20.00
Total	$63.43
Average cost per tree for pulling	0.0509

The trees were removed by teams, which chained them to a deep gully, into which they were rolled without further handling. The cost of removing trees was:

Two teams 3 days at $3	$18.00
Average per tree	0.014

The total cost of pulling and removing was $0.0649 per tree.

The following notes on stump burning by Mr. Le Roy Allison were in *Engineering Record*, July 25, 1914.

The cost per acre of clearing lands varies considerably with the character of the sub-soil, condition of land, etc., but a fair average basis for the Pacific Northwest may be taken as follows:

Method	Average cost per acre
Powder and horse puller	$110
Powder and team	100
Donkey engine	90
Powder and grubbing	80
Powder and burning	70

A complete land clearing plant that combines the different generally used systems into one plant so that any condition of

land may be cleared is operated by a gasoline engine. It consists of a five fire stump burner, a cordwood saw, a power grubber to use with stump pullers, a geared horse stump puller and a power stump puller.

One of the features of the plant is the stump burner which is operated by a blower on the machine. A line of pipe connects the blower to a sheetiron hood by means of a gooseneck, entering the hood through an aperture in the top. This hood is made in four sections and is set over the stump to be demolished.

The use of the burner is particularly simple. A hole is bored down through the center of the stump and a small stick of powder is employed to split it apart. This splitting, while not entirely essential, facilitates in allowing the fire started on top of the stump to gain rapid headway and burn more evenly. The hood is then placed over the stump and banked up with a little earth at the bottom and forms a closed but not airtight chamber. The fire is then started and pipe connection from the blower made, after which a constant downblast is blown upon the flame, continually fanning it.

Stumps are consumed in this manner in from 2 to 4 hr., depending on the size and nature, while those of excessive diameter and unfavorable condition may require a long period. During the operation of the machine the heat within the chamber becomes intense and the sheet iron red hot, making a veritable charpit. The hot air rising from the hood creates a partial vacuum, drawing in the cold air around the outside of the hood. thus preventing it from burning out.

Upon removal of the hood following the consumption of the stump the fire is covered with dirt, allowing the roots to charpit to the ends without the aid of the blower.

Official tests of the burner apparatus have been made, showing effective results at low cost. At Gladstone, Ore., a water-soaked stump 20 ft. in circumference at the base, 13 ft. in circumference at the top and 4 ft. high was used for test purposes.

The equipment used consisted of a 4-hp. gasoline engine, a No. 3 Buffalo pressure blower and a line of 4-in. pipe, with hood and gooseneck. A 2-ft. vertical hole was bored in the stump from the top with a 1-in. auger to accommodate a stick of dynamite used for splitting. Confining the heat by the sheet-iron hood caused rapid combustion of this heavy, water-soaked timber. The stump was consumed in 6 hr. The total cost was $1.15, divided into 75 cents for gasoline for engine operation and 40 cents for explosives.

The method of operating a complete machine advantageously

will be readily understood. It is set on a corner of the land to be cleared and five stumps in the immediate vicinity are split, fired and placed under the blower blasts. These require no particular further attention until consumed. Second-growth trees are meantime pulled out and sawed into cordwood, the roots and snags being thrown into the neighboring fires to be burned. With the power grubber all the undergrowth and small roots are removed.

Subsequently the machine is removed to another position and these operations repeated. By this method a strip of 50 to 100 ft. wide across the property is left ready for immediate plowing and seeding while the machine is engaged in clearing other sections. The noticeable value of the plant is in the expedition with which the work is executed, the reduced cost and the clearing of the land without waste of the vegetable mold which makes it so fertile and productive.

Where there are a number of large stumps or trees to act as dead men, the use of stump pulling machines is economical. Where there are no natural dead men, the machine must be anchored by means of large butts driven in the ground.

Stumps are pulled with a direct pull, the cable running from the stump to the machine, or with a double pull, the cable running through a block fastened to the stump and being attached to another dead man.

A long cable should be used, as the machine is then moved fewer times. A 60-foot cable will clear about ¼ acre, an 85-foot cable about ½ acre, a 100-foot cable ¾ acre, a 150-foot cable 1½ acres, a 200-foot cable nearly three acres, from one set-up.

Steam Driven Stump Pulling Machine. An outfit designed for use in clearing land where the area to be cleared is considerable, first hauls in and stacks or loads the logs, and then pulls the stumps and hauls them in piles to be burned. It is designed to clear 5 acres at a single average set, or an area approximately 600 ft. wide by 350 ft. deep; pulling all stumps within this area, skidding them to the pile, and piling them.

After one area is completed the machine moves under its own power to repeat the operation. The frame of this machine consists of steel beams, curved up at the ends to facilitate moving. On the forward end of the frame is mounted a steel A frame which supports the piling boom. On the rear of the frame is mounted a hoisting engine and boiler. This machine is made in several sizes. No. 1 machine has a maximum pull of 145,000 lb. on a single line with a speed of from 30 to 350 ft. per min. for skidding the stumps to the machine after pulling. The middle

drum of the engine carries the piling line which has a load capacity of 10 tons. All operations are controlled by a single operator. The shipping weight of this machine is approximately 71,000 lb. The smaller size machine has a pulling capacity of 110,000 lb. and a skidding speed of from 30 to 300 ft. per min. They cost from $10,250 to $12,350 f. o. b. Minnesota.

The following gives the cost of operating one of these machines and is from *Engineering News,* Sept. 24, 1914.

One piece of clearing done in Texas was on heavy clay land with pine stumps 10 to 40 in. diameter averaging 44 per acre. The machine pulled, skidded and piled about 110 stumps per day, at a cost of about 28 ct. per stump, or $12.32 per acre, clearing about 2½ acres per day. The working force was as follows, with a total daily cost of $30:

1 Foreman	$5.00	2 Hookers (each)	$2.00
1 Engineman	3.50	1 Tongman	2.00
1 Leverman	2.00	1 Stump grubber	1.50
1 Fireman	2.00	1 Water team	4.00
1 Helper	2.00	1 Fuel team	4.00

Horse Power Stump Puller. A make of pullers, f. o. b. Iowa, is as follows:

Hp.	Horses	Machine with cable	Power pulley with cable	Stump hook	Extension cable	Approx. wt. lb.
54	1	$128.00	$16.50	$10.00	$20.00	700
89	2	180.00	22.50	13.00	23.75	1100
117	2	200.00	28.00	15.75	29.25	1325
168	2	240.00	43.50	17.75	36.00	1650

Another make, f. o. b. Illinois, costs as follows:

Hp.	Horses	Feet cable	Approx. wt.	Price, complete
52 to 104	1	100	620	$120
104 to 156	2	150	750	165
128 to 256	2	200	1120	255

Bed timbers, for self-anchoring, for the above machines cost from $6 to $12 and weigh from 300 to 750 lb.

Sweeps cost from $4 to $8 and weigh from 150 to 200 lb.

A rotary power attachment for the above machines costs $38 and weighs complete 650 lb.

Price of wire rope for grubbing machines:

Size	Price per ft.
⅝	$0.285
¾	.375
⅞	.465
1	.610
1⅛	.770
1¼	.925

Hand Power Stump Puller suitable for smaller work, and capable of pulling from 50 to 70 stumps per day depending on conditions, weighs about 250 lb. for shipment and costs $45 net f. o. b. Pennsylvania. The operation of this machine is as follows: The machine is placed at the side of the stump to be pulled with the chain around the root. Grips on the pulling bar are then taken up and the stump is pulled by the pressure on the hand lever.

Another make of hand power stump puller in the form of a winch costs $40 with 50 ft. steel cable, stakes and chain. It is suitable for pulling small stumps.

A handy tool for use in pulling lateral roots and small stumps was described in *Engineering and Contracting* as follows.

A tool that has given good service in connection with the tripod stump puller and dynamite in the clearing of sandy white pine stump land is used as a lever over which the team pulls to give additional power for the pulling of lateral roots and small stumps left in the ground by either the dynamite or the large puller.

The log chain is passed through the ring at the top of the triangle and then around the snag or root to be pulled. The triangle is set up, the top leaning towards the object to be pulled. As the horses tighten up on the chain, this gives a lifting power as well as a straight pull and as it comes over towards the team the power of the team is about tripled.

The two sides of the triangle are made of 4 x 4's and are about 4½ ft. long. The bottom side is made of a heavy round piece of wood and is 2½ ft. long. The ring is fastened into the top with a heavy bolt.

SECTION 95

SURVEYING AND ENGINEERING EQUIPMENT

(See Levels, Drawing Boards and Transits)

		Price
Beam compass		$17.00
Set of drawing instruments	$9.00 to	30.00
Protractor, 6 inch		1.80
Engineer's triangular scale, 12 inch		2.20
Architect's triangular scale, 12 inch		2.20
45 deg. transparent triangle, 6 inch		.55
45 deg. transparent triangle, 10 inch		1.20
30 by 60 deg. triangle, 6 inch		.50
30 by 60 deg. triangle, 10 inch		.90
Set Railroad curves	6.75 to	68.00
Set French curves	4.00 to	10.00
T square, fixed head, wood, 36 inch	.60 to	1.50
T square, double head, wood, 36 inch	1.00 to	2.10
Thumb tacks, dozen		.70
Water colors, per pan		.30
India ink, bottle		.25
Leveling rod, Philadelphia		18.00
Florida rod, 12 ft.		12.00
Range poles, 10 ft.		5.20
Plumb bob, ¾ lb.		2.25
Stake tacks, each		.15
Marking pins or arrows, set		1.60
Tape mending tool		4.50
Tape mending sleeves, dozen		.50
Steel tape, metal reel, 100 ft.		7.50
Steel tape, metal reel, 50 ft.		6.25
Cloth tape, leather case, 100 ft.		5.85
Planimeter		25.00
Pantograph		2.75

SECTION 96

TAMPERS

Concrete Tampers with square cast iron bases, with 4 ft. hard wood handles weighing 16 lb., 6 by 8 in., $1.50; 19 lb., 8 by in., $1.70; and 27 lb., 10 in., $2.20.

Dirt Tampers with 4 ft. handles, round base, 6 in., 15 lb $1.60; and 7 in., 17 lb., $1.80.

Steel Face Tampers with 4 ft. handles, 8 by 8 in.; weight 1 lb., $2.00; and 10 by 10 in., weight 18 lb., $2.20.

Paving Rammer for granite weighs 56 lb. and costs $16. Cobblestone rammer, weight 50 lb., costs $12.80.

Power Tamping Machine. Fig. 317 consists of a two-wheeled

Fig. 317. Power Tamping Machine.

truck on the rear end of which is an air cooled gasoline engine battery box and gasoline tank, which drives by a belt a hard wood "lifting board" with a cast iron head. The tamper is lifted by the power of the engine and allowed to fall by gravity. Only one man is necessary to operate the machine, and the manufacturer claims that it will strike 60 blows per minute. On this basis, allowing 50% for lost time and wasted strokes, the head, the area of which is ½ sq. ft., will cover 7,200 sq. ft. in one day of 8 hr., or in a trench 3 ft. wide and 5 ft. deep, tamped in 6 in. layers, will cover 240 lineal ft. of trench. This machine

is made in two sizes. The No. 1 size will tamp a trench up to 4 ft. in width. The area of the face of the tamping head is 72 inches, the machine with 1½ hp. engine weighs 1,240 lb. for shipment and costs $330., f. o. b. Springfield, Ill. The larger machine has a tamping head of 110 sq. in., will tamp a trench up to 5 ft. in width, weighs 1,930 lb. for shipment and costs $385. This machine is powered with a gasoline engine of 2½ hp.

Power Traction Tamper. A machine adaptable to tamping backfill, picking pavement, and similar work is illustrated by Fig. 318. It is operated by a 3 hp. gasoline engine. The tamping head weighs 150 lb. and has a 26 in. stroke. The machine has a road speed of 1⅓ miles per hr., and a tamping speed of 6 ft. per min. It costs f. o. b. Milwaukee, $785. This machine is operated by one man.

Fig. 318. Power Traction Tamper.

Pavement Breaker. The following description of this machine, built by Mr. R. A. Mercier, appeared in the *Engineering News Record*, Jan. 7, 1917.

Two types of concrete breakers, one of which is shown in Fig. 319, were built for tearing up paving over the line of trenches for conduits, gas or water mains. Both are run by gasoline engines. The leads on one are hinged to the fold down for moving,

Fig. 319.

while the leads on the other are pivoted to swing to an arc of 6-ft. length, so that quite a wide trench can be broken in one movement of the machine.

After removing the wearing surface, the machine straddles the line of tracks, and the 600-lb. hammer, fitted with a wedged-shaped point, is raised and dropped to break up the base. The frame, brace members, leads and arc of the pivoted machine are made of 6-in. channel iron. The leads are lined with oak and are 9 ft. long. A pole inserted between straps on one of the horizontal braces is guided by one man to locate the hammer blows. The hammer is controlled by an ordinary 8-in. hand-operated clutch and foot brake, the clutch being geared to the 7-hp. gasoline engine. The machine is pulled along the line of the tracks by a hand windlass and rope attached to a bar driven in the pavement some distance ahead. It can be moved from job to job with ease by one team. It is also capable of cutting sheet asphalt to a very accurate line.

The second machine is provided with a chain drive instead of gears.

Each of these cost about $975 to build at the time. The cost of building similar machines at the present time would be approximately $1,500 complete.

Comparative Cost of Machine and Hand Tamping. The following is from an article by Mr. C. W. Wilson in *Municipal Engineering*, May, 1916.

On work at Superior, Wis., in connection with a large conduit installation, four miles of trench backfill was tamped by hand and approximately 6,000 feet mechanically tamped. Bell tampers, 5 inches in diameter, were used by the workmen, while the head of the machine-tamping ram measured 9 by 12 inches. The average depth of trench was 3 feet, average width 18 inches. The material consisted of a red clay of exceedingly tough texture, which, when wet, was almost impossible to tamp by hand, but the tamper thoroly compacted it at an approximate saving of 6 cents per linear foot over hand tamping.

The machine was a power traction tamper, equipped with a 3-hp. 4-cycle engine. On this job accurate cost records were kept, so as to determine the actual dollars and cents difference between the two methods. The conditions under which the hand tampers competed with the machine were identical.

Length of trench in ft.	Method	Cost	Cost per ft.
464	machine	$ 9.13	$0.019
417	machine	5.06	.012
466	machine	16.90	.036
427	machine	8.88	.020

322	hand	23.80	.073
345	hand	25.53	.074
320	hand	24.80	.075
320	hand	29.80	.093
358	both methods	19.85	.055

The machine, while tamping, travels at the rate of approximately 9 feet per minute, or 540 feet per hour. The machine keeps six to eight shovelers busy, depending on the nature of the soil, and there is considerable satisfaction in knowing that after the machine has gone over the trench it is properly and thoroughly compacted.

In order to accomplish the same result by hand as obtained by machine, it would be necessary to use eighteen tampers with the six shovelers, at a cost of 25 cents per hour, or a total cost of $8 per hour; whereas with the machine the cost for labor, not figuring the cost of the operator, $1.50 per hour, effects a saving of $6.50 per hour.

Compressed-Air Driven Rammers for use in foundries are economical because of their simple construction and the large amount of work they will accomplish. Owing to their lessening the manual efforts of the moulder, they enable him to accomplish

Fig. 320. Rammers at Work on Sewer Covers.

from four to twelve times as much work as under the old hand methods. These rammers are especially adapted for the manufacture of concrete building blocks, pier foundation blocks, sewer covers, chimney cap, window sills, curbing, etc.

The prices of rammers are as follows:

Size, inches	Used for	Weight in lb.	Price f. o. b. factory
⅞ by 4	Bench work and cores	7	$80
1¼ by 7	General floor work	24	90

Tie Tampers primarily designed for tamping ballast on railroad track may also be used for breaking up asphalt and concrete paving, in the picking out of paving blocks, breaking up frozen material and, also, for drilling in soft rock. A tamper weighing about 43 lb. with connections costs $110 without attachments. Cutting or tamping bits cost about $3 each. This machine is best operated at a pressure of 70 lb. and has an air consumption of 16 cu. ft. free air per min. at this pressure.

Comparative Cost of Tie Tamping by Hand and by Pneumatic Outfit. A competitive test conducted on one of the large railroads, Hand vs. Machine tamping, using a four-tamper gasoline outfit, was as follows:

	Number of men	Time hours	Feet of track tamped
Hand gang .... Foreman.	16	8	500
Machine gang .... Foreman.	6	8	528
Saving	10	Time 80 hours	28

	Number of men	Wages	Expenses operating overhead, etc.	Total
Hand gang .... Foreman.	16	$43.50		$43.50
Machine gang .... Foreman.	6	$18.50	$6.95	$25.45
Saving	10			$18.05

Saving in Favor of Machine Tamping

In tamping season of 200 days at $18.05 .... $3,610.00

SECTION 97

TELEPHONES AND TELEPHONE LINES

Cost of a Construction Service Telephone Line in Cuba. Specifications: Length 15 miles, 464 poles, line is 2-wire metallic circuit No. 12 B. & S. gauge, hard drawn copper wire, oak brackets, glass insulators, poles spaced 171 feet apart.

	Per mile
Digging holes	$ 32.71
Squaring poles, etc.	14.19
Setting poles	135.65
Stringing wire	78.73
Tools	2.86
General	4.45
Total, prior to 1910	$268.59

The following costs have been compiled from an article in *Engineering and Contracting*, 1908, on the cost of building a high power transmission line. The average length of haul was one mile. The wages paid per 10-hour day were:

Foreman	$3.00
Laborers	1.50
Lineman	2.50
Team, 2 horses and driver	4.50

The poles were of chestnut 30 to 33 ft. long, 5 to 9 inches at the top, and 12 to 18 inches at the bottom. Seventy-four poles, 8 to 10 on a load, were unloaded from cars and hauled to the work for $30. Seventy-four holes, 5 ft. deep and an average of 24 inches in diameter were dug at a cost of $72.75 or 98 cents per hole. Poles were raised by hand at a cost of $56.75 or 76 cents per pole, and were dapped for the cross arms at a cost of $22.62 or 9.8 cents per dap. One hundred and sixty-six cross arms, well braced, were placed at a cost of $27.62 or 17 cents per cross arm. Nine hundred and ninety-six insulators were placed at a cost of $6 or 0.6 cents per unit.

At all the turns the poles were guyed, and elsewhere where necessary. The cost of digging the holes for this was $8.25 or 92 cents per hole. Raising the poles cost $12, and guying them $9, or a total of $3.25 per guy pole. In some places trees and

bushes interfered with the work and these were cut down for $33.50.

Twelve light wires were strung on each pole at a cost of $118.50 for 21.6 miles or for $5.50 per mile of wire. Where the line was connected with the old line 4 poles had to be changed, which cost $56.50 or $14.12 per pole.

The cost of the entire 1.6 miles of line was:

Item	Total cost	Per mile
Hauling	$ 30.00	$ 18.74
Digging holes	72.75	45.47
Raising poles	56.75	35.47
Dapping cross arms	22.62	14.14
Placing cross arms and insulators	33.62	21.01
Guy poles	29.25	18.28
Trimming trees and bushes	33.50	20.94
Stringing wires	118.50	74.06
Changing old poles	56.50	35.31
Total	$453.49	$283.42

The following itemized cost of two telephone lines is taken from *Engineering and Contracting*, 1907.

Two short lines were built, one 10 miles long and the other 14 miles long. The cost of the 10 mile line was as follows per mile:

Labor.

1.7 days foreman at $4.00	$ 6.80
1.7 days sub-foreman at $3.00	5.10
4.0 days climbers at $2.50	10.00
10.5 days groundmen at $2.25	23.63
17.9 days total at $2.54	$45.53

Materials.

28 poles at $1.50	$42.00
28 cross arms at $0.15	4.20
28 steel pins at $0.04	1.12
28 glass insulators at $0.04	1.12
56 lag screws and washers at $0.015	.84
305 lb. No. 9 galvanized wire at $0.042	12.81
Total	$62.09

Total labor and materials, $107.62 @ $10.76 per mile.

More than 90% of the poles were 25 feet long. The rest were 30 to 40 feet in length.

The cost of the 14 mile line was as follows, per mile:

Labor.

2.2 days foreman at $3.50	$ 7.70
2.2 days sub-foreman at $3.00	6.60
5.3 days climber at $2.75	14.58
11.4 days groundman at $2.25	25.64
21.5 days total at $2.54	$54.52

MATERIALS.

32 poles at $1.50	$ 48.00
32 brackets at $0.015	.48
380 lb. No. 8 galvanized wire at $0.042	15.96
10 lb. No. 9 galvanized wire at $0.042	.42
1½ lb. fence staples at $0.025	.04
32 insulators at $0.04	1.28
Total	$ 66.18
Total labor and materials	$120.70
2 telephones at $12.50	25.00
200 ft. office wire	1.40
Total	$213.28 @ $15.24 per mile

Considering the low cost of telephone lines of this character, it is surprising that they are not more frequently built for use on construction work. For temporary purposes, a much cheaper kind of pole could be used. For example, a very substantial pole can be made by nailing together two 1 x 4-in. boards, so as to form a post having a T-shape cross section. Such a pole would contain only two-thirds of a foot, board measure per lineal foot of pole. At $24 per M. for the boards, a pole 20 ft. long would cost 32 cents. Hence the poles would cost less than $10 per mile of line. The No. 9 wire would ordinarily cost less than $13 per mile, and $3 more would cover the cost of the remaining line materials, making a total cost of $26 per mile for materials. I have no data as to the labor of erecting such a line, but it would certainly be less than $15 per mile; and in soil where post hole diggers could be used, the cost would be considerably less. In fact, a telephone line built for $35 a mile might easily be obtained under fairly favorable conditions. Moreover, it could be taken down and used many times on subsequent construction. These figures are as of 1910.

SECTION 98

TENTS AND CAMP EQUIPMENT

Tents are usually made of 8 oz., 10 oz., or 12 oz. single filling canvas, 10 oz. or 12 oz. double filling canvas, or of 10 oz., 12 oz. or 15 oz. Army duck.

Fig. 321. Wall Tent.

WALL TENTS WITH POLES, STAKES AND ROPES.

Size in ft.	Height of center	Height of wall	8 oz. duck single filling	12 oz. U. S. Army duck
7 by 7	6½	3	$ 12.80	$ 21.80
8 by 10	6½	3	18.00	28.90
9 by 14	7	3	24.60	42.00
11 by 14	8	3½	30.60	52.30
11 by 21	8	3½	41.00	72.50
14 by 14	9	4	36.90	63.20
14 by 21	9	4	49.30	86.60
16 by 21	10½	5	60.00	105.00
18 by 21	11	5	67.50	157.00
18 by 42	11	5	123.00	206.00
21 by 21	12	5	83.50	129.00
21 by 42	12	5	135.00	226.00
23 by 35	13	5	130.00	218.00
23 by 63	13	5	207.00	346.00

Prices do not include flys, which cost about one-half of the price of the tent up to 31 ft. lengths.

Standard Mule or Dining Fly.

Size	10 oz. Army duck
24 by 21	$ 65.00
24 by 42	130.00
24 by 70	218.00
26 by 35	113.50
26 by 49	161.00
28 by 42	148.00
28 by 56	198.00
30 by 42	156.00
30 by 70	264.00

Prices are for flys with guy ropes, but no poles or stakes.

Standard Stable Tents.

Size	Height of center	Height of wall	10 oz. Army duck
24 by 21	12	5	$150.00
24 by 35	12	5	220.00
24 by 49	12	5	280.00
24 by 63	12	5	360.00
26 by 28	12½	6	200.00
26 by 56	12½	6	325.00
26 by 77	12½	6	455.00
28 by 35	14	6	280.00
28 by 49	14	6	370.00
28 by 70	14	6	500.00
30 by 21	14	6	215.00
30 by 42	14	6	345.00
30 by 70	14	6	500.00
30 by 84	14	6	600.00

Prices complete with poles, stakes, guy ropes and tackle blocks for setting up.

Fig. 322. Stable Tent.

The Cost of Framing and Flooring Tents is given by Mr. R. C. Hardman of Fort Huachuca, Ariz., in *Engineering News*, September 26, 1912, from which the following is abstracted:

The tents were of two sizes, viz: 14 ft. x 14 ft. 2 in., and 6 ft. 11 in. x 8 ft. and were framed with 2 x 4 in. timber, braced with 1 x 6 in. timber and floored with 1 x 12 in. plank. The larger tent had 4 pairs of rafters and the smaller 3 pairs. The costs were as follows:

Large Tent:

500 ft. B. M. lumber at $30.00	$15.00
7 lb. nails at $0.05	.35
	$15.35

Small Tent:

185 ft. B. M. lumber at $30.00	$5.55
5 lb. nails at $0.05	.25
	$5.80

Labor Cost of Flooring and Framing

Tents 14 ft. x 14 ft. 2 in.

38 Frames:

	Cost	Cost per tent
Carpenters, 32 hours at $0.50	$16.00	
Carpenter helpers, 129 hours at $0.375	48.38	
Laborers, 19 hours at $0.25	4.75	
Laborers, 11 hours at $0.20	2.00	
	$71.33	$1.877

42 Floors, Average Height 1 Ft. Above Ground, Leveled:

Carpenters, 72 hours at $0.50	$36.00	
Carpenter helpers, 153 hours at $0.375	57.38	
Laborers, 81 hours at $0.25	20.25	
Laborers, 19 hours at $0.20	3.80	
	$117.43	2.796
		$4.673

Tents 6 ft. 11 in. x 8 ft. 4 in.

16 Frames:

Carpenters, 5 hours at $0.50	$ 2.50	
Carpenter helpers, 23 hours at $0.375	8.75	
	$11.25	.703
		$1.594

16 Floors, Average Height 1 Ft. Above Ground, Leveled:

	Cost	Cost per tent
Carpenters, 9 hours at $0.50	$ 4.50	
Carpenter helpers, 26 hours at $0.375	9.75	
	$14.25	$0.891

Total Cost of Frame and Floor:

	Large tent	Small tent
Material	$15.35	$5.80
Labor	4.67	1.59
	$20.02	$7.39

SECTION 99

TIES

The following shows the number of cross ties required per mile of track:

Distance from center to center (in.)	No. of ties	Distance from center to center (in.)	No. of ties
18	3,520	36	1,748
21	3,017	39	1,613
24	2,640	42	1,497
27	2,348	45	1,399
30	2,113	48	1,300
33	1,905	51	1,233

The quotation at the mills in Missouri, January, 1920, for white oak untreated ties, was from 70 to 98 cents for the 6 by 8 by 8 size. The ordinary contractor's tie suitable for narrow gauge track is generally purchasable at about 50 cents. Ties 4 x 4 in., in sections, are too small, as they split easily, and, therefore, ties smaller than 6 x 4 in. should never be used. Ties used in narrow gauge tracks should be 2 ft longer than the gauge.

Thirty-five standard gauge ties may usually be cut from a pine tree that is 14 in. in diameter at a height of 5 feet above the ground. A skilled man can cut and trim 40 to 50 of these ties per day. The cost of cutting and hauling ties, provided the timber is growing in the immediate neighborhood, need not be more than 10 cents per tie.

The life of a tie depends largely upon its suitability for resisting the particular kind of attacks incidental to its surroundings. Oak ties in the fairly dry localities will hold spikes with great tenacity, and at the same time resist the effect of dampness very well, and may last 8 to 10 years. Under less favorable conditions, however, they may not last more than 7 years when untreated, while if thoroughly saturated with creosote or zinc sulphate, the average life may be 17 years.

The following table shows the life and cost of ties, etc. (1910 figures):

	Wood				Concrete	
	Un-treated	Treated	Steel	C. I.	Rein-forc.	Stand'd beam
Life in years	8	20	25	30	8	14
Cost delivered	.90	1.60	4.25	5.25	2.30	3.25
Cost of renewal	.12	.12	.15	.15	.18	.18
Cost in track	1.02	1.70	4.40	5.40	2.48	3.43
Value wornout ties	...	...	.85	.75	.20	.53
Spacing c to c in ft.	1.875	1.875	2.	2.	2.	2.
Cost per lin. ft. track	.544	0.917	2.20	2.70	1.24	1.76
Value scrap per lin. ft. track	...	...	.42	.37	.10	.26
Annual cost ties per lin. ft. track	0.81	0.067	0.131	0.149	0.173	0.152
Annual cost 1 mile track	427.68	353.76	691.68	786.72	913.44	802.56

The above costs are determined by substituting in the following formula:

$$x = ci + (c - v)s \qquad \text{If } v = o \qquad x = c(i + s)$$

where

- x = Annual cost of ties per linear foot of track.
- c = First cost in track per linear foot of track.
- v = Value of wornout tie per linear foot of track.
- L = Useful life of tie in years.
- i = Interest rate per annum.
- s = Annual payment into a sinking fund, which at the rate i for L years will amount to one dollar.

In the above table i = 4%.

Track used on construction work is frequently moved. The ties will stand about three removals, and are then unfit for further use.

Mr. D. A. Wallace gives the following costs of unloading ties. Cost of train service:

Cost of work train, $25 00 per day; foreman, $50.00 per month; labor, $1.10 per day.

From coal cars while running: Train service, $1.04; labor, $0.45 — total, $1.49; 250 ties at 0.6 ct. per tie.

Box cars while running: Train service, $6.24; labor, $5.35 — total, $11.59; 970 ties at 1.2 ct. per tie.

Nine coal car work trains unloading in spots from 6: 15 a. m. to 6: 15 p. m. The cost of unloading per tie was: Delays, 0.48 ct.; unloading time, 0.29 ct.; running time, 0.83 ct.; total, 1.60 ct.

Above are 1910 figures.

SECTION 100

TOOL BOXES

Contractor's Tool Cart having an overall length of 10 ft. 5 in. with 42 in. wheels weighs approximately 675 lb. and costs f. o. b. New York $70.

Gas Fitter's Tool Cart with 42 in. wheels arranged so that a vise may be mounted on it, has a compartment 24 by 48 by 14 inches, weighs 340 lb. and costs $45 f. o. b. New York.

Tool Box on skids shown in Fig. 323 is easily moved by one man and team, and of ample capacity. The box proper is made 6½ ft. long inside by 3 ft wide, 2½ ft. high in front and 4 ft. high behind. All measurements except the first are outside dimensions. The small box increases the length about 2 ft. and is 2 ft. high on the low side. The runners should be of 3 x 8 in. by 10 ft. with eye bolts, so the box may be pulled from either end. The upright posts are of 2 x 4 in. pieces and extend 6 in. down alongside the runner. The ones at the rear of the box are brought 6 in. above the top to support the lid when open. The 2 x 4 in. pieces on which the floor is laid are let into the runners at least an inch and are spaced when possible so the uprights are directly against them. This construction makes a very strong box that may be handled very roughly without damage. The smaller compartment is especially convenient for nails, oil cans, and small tools.

The cost of the materials for this tool box is about $15.

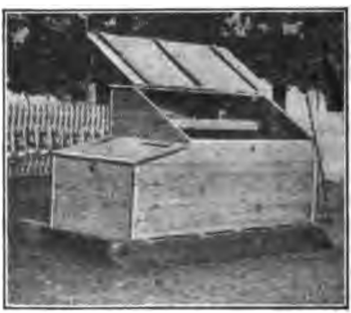


Fig. 323. Tool Box on Skids.

SECTION 101

TOW BOATS

Under "Barges" are described a number of such boats used on the upper Mississippi and whose cost, life and cost of repairs are described. I herewith append a list of tow boats used on this improvement.

Tow Boats. There are three sizes of tow boats used which are designated as large, medium and small. Of the boats mentioned in the following tables, the *Coal Bluff, Fury, Henry Bosse* and *Alert* are in the first class; the *Ruth, Mac,* and *Grace* in the second; and the *Lucia, Louise, Elsie, Emily* and *Ada* in the third. The *Elsie* was built with a steel hull, and the wooden hull of the *Louise* was changed to steel in 1905.

The *Fury* and *Henry Bosse* (formerly the *Vixen*) were built under contract at Dubuque, Iowa. Their hulls are of oak, 100 ft. x 19 ft. 6 in. x 3 ft. 10 in.; cylinders, 10½ in. x 4 ft.; one boiler, 22 ft. x 42 in., with ten 6-in flues. Both of these boats have been rebuilt with somewhat different dimensions. On December 31, 1910, they were classed as fair, which means that extensive repairs were needed.

The *Alert* was bought second-hand; hull, oak, 115 x 19 x 3 ft.; cylinders, 10 in. x 5 ft.; one boiler, 16 ft. x 43 in.; rebuilt in 1884 and partially rebuilt several times. December 31, 1910, in bad condition.

The *Coal Bluff* was bought second-hand, 3 years old; hull, oak, 120 ft. x 22 ft. x 4 ft. 6 in.; cylinders, 15 in. x 5 ft.; three boilers, 25 ft. x 36 in.; hull twice rebuilt and also very large repairs; condition, bad.

The *Mac* was bought nearly new; oak hull, 73 x 16 x 3 ft; cylinders, 7 in. x 3 ft. 2 in.; one boiler, 14 ft. x 36 in.; hull has never been entirely rebuilt, although large repairs were made in 1894, 1902 and 1910; condition, good.

The *Ruth* was built by the United States; hull, oak, 75 ft. x 17 ft. x 3 ft. 3 in.; cylinders, 7 in. x 4 ft.; two boilers, 10 ft. x 30 in.; hull has not been entirely rebuilt, but received large repairs in 1901 and 1909; condition, good.

The *Grace* was built by the United States; hull, oak, 79 x 17 ft.; cylinders, 7 ft. 6 in. x 4 ft. 1 in.; two boilers, 10 ft. x 30 in.;

TOW-BOATS (LARGE AND MEDIUM), OAK HULLS.

	Year	*Fury*, built 1881	*Henry Bosse*, built 1881	*Alert*, built 1874; rebuilt 1881	*Coal Bluff*, built 1878; rebuilt 1881	*Mac*, built 1891; rebuilt 1893	*Ruth*, built 1895	*Grace*, built 1904
Original cost	....	$11,976.00	$11,976.00	$ 6,000.00	$ 8,000.00	$ 2,500.00	$ 6,426.47	$8,616.37
Repairs to	1890	6,292.71	10,432.01	*14,202.00	*25,769.09	....	....	....
Repairs	1891	‡3,187.09	‡2,032.26	133.32	....	....	....	....
Repairs	1892	426.35	588.95	409.31	‡3,628.02	....	....	....
Repairs	1893	1,973.82	375.52	‡1,586.61	‡2,236.53	653.06	....	....
Repairs	1894	255.93	749.85	‡1,770.12	1,283.67	‡1,379.93	....	....
Repairs	1895	†3,364.32	*5,050.51	559.08	702.83	362.34	....	....
Repairs	1896	2.90	272.45	590.88	215.86	539.22	99.44	....
Repairs	1897	463.70	232.30	‡1,938.49	1,028.62	430.38	159.28	....
Repairs	1898	497 46	200.42	‡1,034.95	72.72	571.35	231.57	....
Repairs	1899	*5,247.28	224.16	‡1,064.78	*9,122.30	400.07	289.95	....
Repairs	1900	147.19	‡1,744.01	191.28	602.44	434.25	397.82	....
Repairs	1901	38.91	231.22	....	223.05	142.09	‡1,112.67	....
Repairs	1902	998.34	629.91	304.47	1,175.51	‡1,862.03	275.00	....
Repairs	1903	495.76	460.44	‡1,619.06	277.86	237.65	338.59	....
Repairs	1904	461.53	523.90	476.68	621.19	195.54	799.11	....
Repairs	1905	583.63	‡3,375.25	692.31	1,612.76	874.04	220.38	119.33
Repairs	1906	1,209.11	61.12	‡1,208.05	858.65	210.01	643.98	28.86
Repairs	1907	‡3,026.34	87.41	‡1,804.35	‡3,204.10	457.66	492.41	225.79
Repairs	1908	337.25	497.52	‡1,574.92	‡3,226.92	631.64	661.29	35.65
Repairs	1909	719.70	695.27	‡1,680.45	280.74	606.00	‡2,881.30	266.00
Repairs	1910	1,178.67	1,210.28	‡2,720.89	‡1,686.93	‡1,927.61	766.30	157.67
Totals	....	$42,883.89	$41,650.76	$41,562.00	$65,829.79	$14,414.87	$15,795.56	$9,449.67

* New hull. † New boilers. ‡ Very large repairs to hull

The total cost of each of the first three boats mentioned in this table appears very small for thirty years' service, and while considering the greatly increased cost of lumber, it may now be advisable to build of steel or iron, it is manifest that wooden hulls in the past were cheaper than metal would have

hull has not been rebuilt or received large repairs; condition, good.

Small Tow-Boats. The *Lucia* was built by the United States at Keokuk; hull, oak, 68 ft. x 12 ft. 8 in. x 3 ft.; cylinders, 6 in. x 2 ft. 6 in.; boiler, 10 ft. x 38 in. She had large repairs in 1892 and 1904, and her hull was rebuilt in 1895 and 1909-1910; condition, December 31, 1910, good.

The *Louise* was built by the United States at Keokuk; hull, oak, 61 x 12 x 3 ft.; cylinders, 6 in. x 2 ft. 6 in.; boiler, 10 ft. x 34 in.; hull rebuilt in 1894; steel hull in 1905; moderate repairs each year; condition, good.

The *Elsie* has a steel hull and was built by contract at Jefferson, Ind.; hull, 67 x 13 x 3 ft.; cylinders, 6 in. x 2 ft. 6 in. boiler, 10 ft. x 34 in. The *Elsie* appears to have cost as much money as the wooden hull *Ada* for the same period of time.

The *Emily* was built by the United States at Keokuk; hull, oak, 67 x 12 x 3 ft.; cylinders, 6 in. x 2 ft. 4 in.; boiler 10 ft. x 34 in.; condition, good; new hulls in 1902 and 1909-1910.

The *Ada* was built by the United States at Keokuk; hull, oak, 68 x 11 x 3 ft.; cylinders, 6 in. x 2 ft. 6 in.; boiler, 10 ft. x 34 in.; condition, good; hull rebuilt 1903-1904.

These small tow boats are of great value with light tows in working around the dams.

Tow-Boats (Small)

	Year	*Lucia*, built 1885	*Louise*, built 1884	*Elsie*, built 1889	*Emily*, built 1889	*Ada*, built 1889
Original cost	....	$ 4,000.00	$ 3,538.00	$ 5,110.00	$ 4,034.00	$ 4,000.00
Repairs to and including	1890	1,560.62	761.25	194.89	175.28	112.70
Repairs	1891	27.79	221.47	200.58	17.57	37.29
Repairs	1892	†1,181.67	......	21.91	350.55	16.55
Repairs	1893	152.45	527.41	519.80	60.82	593.18
Repairs	1894	296.10	*3,010.99	387.87	154.74	791.11
Repairs	1895	*2,286.84	399.96	619.02	328.06	730.04
Repairs	1896	331.57	333.86	102.63	48.25	262.94
Repairs	1897	137.51	84.67	227.11	854.42	475.93
Repairs	1898	58.11	96.22	534.62	55.54	557.22
Repairs	1899	142.25	60.10	112.64	86.74	142.20
Repairs	1900	78.64	565.27	35.52	166.64	47.15
Repairs	1901	87.73	......	1.26	......	......
Repairs	1902	156.02	323.20	319.63	*2,908.74	394.54
Repairs	1903	75.07	349.21	87.42	12.10	*1,045.64
Repairs	1904	†1,086.20	259.12	751.60	103.56	*1,583.06
Repairs	1905	44.51	‡2,991.17	266.49	205.28	50.60
Repairs	1906	80.52	326.60	194.43	82.49	136.75
Repairs	1907	453.22	368.42	583.86	410.16	328.19
Repairs	1908	186.60	212.91	807.72	447.80	127.21
Repairs	1909	*1,107.44	62.47	331.29	*850.31	364.00
Repairs	1910	*3,044.29	541.18	1,150.08	*3,123.56	454.30
Totals	....	$15,485.15	$15,033.48	$12,560.37	$14,476.61	$12,250.60

* New hull built. † Large repairs. ‡ New hull built, steel.

All of these boats, except the *Elsie*, had wooden ¾-hulls when built. The *Elsie's* hull is steel and the *Louise* has also a steel hull since 1905. The *Elsie*, *Emily* and *Ada* were built in the same year, and the cost of the two latter compares favorably with the former.

SECTION 102

TRACTORS

A make of traction steam engine mounted on wheels, similar to the one shown in Fig. 324, is priced as follows:

Rated hp.	Miles per hour	Approximate weight in lb.	Price f. o. b. Wisconsin
30	2.40	11,000	$2,000
40	2.35	13,000	2,900
50	2.30	14,000	3,200
60	2.61	16,000	3,250
65	2.40	17,000	3,500
75	2.50	20,000	3,550
80	2.39	20,500	3,900
110	2.37	32,600	4,000

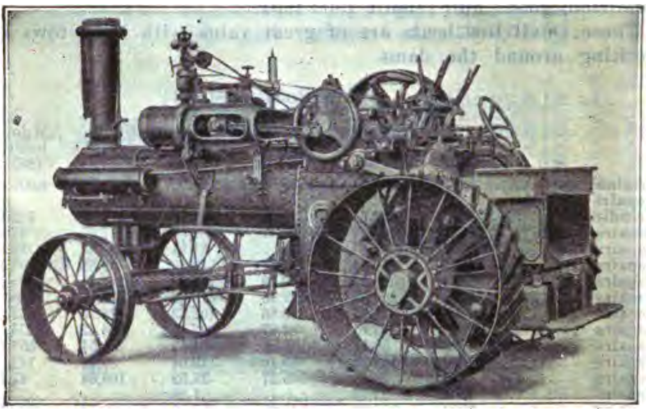


Fig. 324. Traction Engine.

Extras for the above are as follows:

Contractors' fuel bunkers for engines in the field	$200
Jacket for 30 to 80 hp. inclusive	75
Straw burning attachment for 40 to 80 hp. inclusive	90
Canopy top for 30 to 80 hp. inclusive	65
Cab for 110 hp.	75

Cost Data on Hauling Stone with Traction Engine. The following is from an article by Mr. J. F. Hammond in *Engineering and Contracting*, March 27, 1912.

In road work in York County, Pa., a 22 hp. steam traction engine was used with stone spreading cars. The wages paid to the engine crew was: Engineer, $3.50 per day; fireman, $1.75 per day, steady time for ten hours daily; overtime at same hourly rate. The fireman operated the stone spreading cars, making the spread of even thickness, which requires considerable experience and should be closely watched by the overseer as the tendency is to spread too deeply, and superfluous stone would have to be removed at an extra expense. Supervision in our case was figured at one-third of the superintendent's time, or $2.28 per day with no extra time allowance. Interest and depreciation are figured on the new value of the machinery—$5,050 on June 1, 1909, and on an estimated life of four years, or 25% depreciation per year, with an interest charge on the capital invested of 5%. The sum of the interest and depreciation, however, are figured for the whole year and divided into the days that we actually worked. This is hardly fair to the machine, as it might have done more days' work and thus reduced this item. The life of the machine is also very conservative, and probably should be eight to twelve years instead of four years.

Total Cost of Operation — 93 days.

Operating	$ 945.67
Repairs	310.17
Depreciation and interest	686.15
Supervision	239.40
Total	$2,181.39

Analysis of Operating Account.

4.70 tons coal at $4.50	$ 21.15
3.49 tons coal at $5	17.45
913.4 tons coal at $3.26	297.77
Water	66.27
67 gal. cylinder oil at 30 ct.	20.10
30½ gal. black oil at 9½ ct.	2.94
333½ lb. grease at 5½ ct.	18.77
71 lb. of waste at 7½ ct.	5.35
Engineer's wages on operation	330.41
Fireman's wages on operation	164.83
3½ gal. kerosene at 10 ct.	.35
1 can of tar at 28 ct.	.28
Total	$ 945.67

Daily Expense.

Supervision wages	$ 2.28
Engineer's wages	3.50
Fireman's wages	1.75
Coal	3.55

Cylinder oil	.21
Black oil (gears)	.03
Grease (cups and gears)	.20
Kerosene	.003
Tar	.002
Waste	.06
Depreciation	6.417
Interest	0.961
Repairs	3.33
Total	$22.293

Tonnage Hauled.

August 1, 1910	1,681
Sept. 1, 1910	1,525
Oct. 1, 1910	1,176
Nov. 14, 1910	284
Total tons	4,666

Cost Per Ton Hauled.

		Cents
Operation	$\frac{945.67}{4,666}$	0.202
Repair	$\frac{310.17}{4,666}$	0.066
Depreciation	$\frac{596.78}{4,666}$	0.128
Interest	$\frac{89.37}{4,666}$	0.017
Supervision	$\frac{239.40}{4,666}$	0.051
		0.464

Extreme haul, 9.44 miles. Start, 5.00 miles.

Average length of haul, 7.22 miles round trip. 2.24 trips daily; 209 trips, or 1,508.98 miles in 93 days.

Gas and Oil Tractors. The following are the prices of this type of tractor (Fig. 325):

Hp.	Fuel	Speed miles per hr.	Price f. o. b. Wis.
9–18	gasoline	2¼ to 3½	$1,200
10–20	kerosene	2½	1,000
15–27	gasoline	1¾ to 2¼	1,700
20–40	gas and oil	2 to 3	2,500
30–60	gas and oil	2	2,700

Another make of gasoline or kerosene tractor may be had with either wheel or multi-pedal traction. A machine of this type rated at 15 to 30 hp., has a draw bar pull of about 15 hp. The speeds are from 1¾ to 3½ miles per hr., the weight is about 4,750 lb., and the cost is $2,250.

A kerosene tractor, rated 10–20, adapted to agricultural work, weighs approximately 3,800 lb., and costs $985 f. o. b. Ohio. It

has a road speed of 2½ miles per hr., and is fitted for belt drive as a portable engine.

A gasoline tractor of the wheel type is made with two sizes of

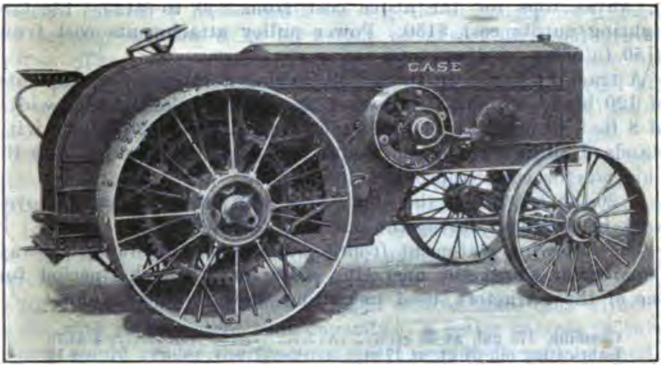


Fig. 325. Gasoline Tractor.

engines. The 4¼ by 5½ costs $1,850, the 4½ by 6 costs $2,000. This machine weighs about 4,500 lb.

Caterpillar Tractors. A make of gasoline-driven caterpillar tractors costs as follows:

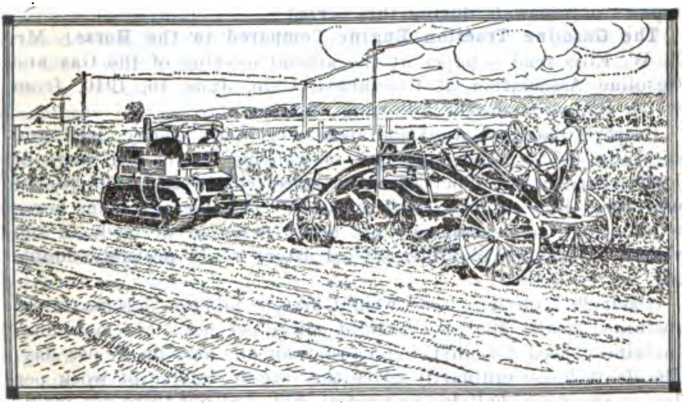


Fig. 326. Caterpillar Tractor.

Size in tons	Draw bar pull in lb.	Approximate weight in lb.	Speed miles per hr.	Price f. o. b. Ill.
5	3,100	9,400	1.5 to 5.7	$3,850
10	5,000	18,600	1.7 to 4.8	5,950

Canvas tops for the above cost from $50 to $125. Electric lighting outfits cost $150. Power pulley attachments cost from $150 to $200.

A tractor similar to the above, having a rated power capacity of 120 brake hp. and 70 drawbar hp., is 21 ft. long, has a width of 8 ft. 8 in. with standard 24 inch tracks, weight 26,500 lb. with standard 30 inch tracks the width is 9 ft. 8 in., weight 27,000 lb. This tractor costs approximately $7,000.

A 20-ton tractor of the above type was used in snow removal work in Michigan during the winter of 1919–1920.

The following statement from a bulletin of the State Highway Department shows the operating costs for a 2-weeks' period for one of those tractors, used in pulling snow roller and plow:

Gasoline, 175 gal. at 25 ct.	$ 43.75
Lubricating oil, 36 qt. at 17 ct.	6.12
Grease, 3 lb. at 12 ct.	.36
Alcohol, 20 gal. at 90 ct.	18.00
	$ 68.23
Labor, 52 days at $4.00	208.00
Total	$276.23

Number of miles of road opened, 55.2.
Unit cost per mile of road, $5.004.

The above costs do not include fixed charges. There were no repairs or renewals during this period.

The Gasoline Traction Engine Compared to the Horse. Mr. L. W. Ellis read a paper at the annual meeting of the Gas and Gasoline Association at Cincinnati, Ohio, June 16, 1910, from which I have made the following abstract:

Properly handled, working about six hours a day, well and carefully fed, a horse may have a working life of ten years of 1,000 hours each. Where used on street car systems, his life of usefulness is from two to four years. The average farm horse will do well to develop 500 hp. hours per year or 5,000 in ten years. A tractor, carefully looked after, would probably double this for each rated hp.

About 20% of the horse's weight may be taken as his maximum sustained draft, and six to eight miles per hour his maximum sustained speed for anything more than an hour or so per day. The draft horse ordinarily gives the largest volume of work per day at about one-half his maximum load, and one-third his maximum speed.

One reason for the great flexibility of the horse is the fact that he works most economically at about 1 lb. of draft for 10 lb. of weight, or from 50 to 20% of the rate he can exert in a pinch. In the motor contests at Winnipeg last year the gas tractors exerted 1 lb. of draft for 4¼ lb. of weight on a good sod footing, and for 6 lb. of weight on a soft dirt and gravel course. The average horse develops one useful horsepower for 1,500 lb. of weight. Nine of these tractors, which completed all the tests, developed 1 brake hp. for 465 lb. of weight, and under both good and bad footing 1 tractive hp. for 922 lb. of weight.

The horse needs a drink and food after every seven to eight miles of plowing, but of course can be forced to go a greater distance. Some of the best known gas tractors could go from 10 to 15 miles under full load if it were possible entirely to empty the fuel and water tanks without stopping. Actually they need water about as often as the horse. Others of different type could go for 15 to 20 miles without fuel and several times that without water, with their present tank capacity. A better balance in this respect would render the tractors more convenient, and undoubtedly some weight would be eliminated in so doing. A steam plowing engine does well to travel two miles on the water taken in during 15 mins. Probably 95% of the weight may be put into metal, 2½% into the cooling water and 2½% into fuel. The latter may be increased easily in tractors designed for use in dry stretches.

The gas tractor cannot compete with the horse as a hauling proposition on heavy grades. The elimination of steep grades, which a horse may surmount by the expenditure of greatly increased energy, but which exhaust the overload capacity of tractors, will mean not only an increased use of mechanical motors for hauling purposes, but an excellent field for traction machinery in the building and maintenance of good roads.

One man in the field may handle four to six horses, developing from 2½ to 4½ hp. Two men on a gas tractor will handle an outfit doing from 10 to 20 times the work. To care for a traction engine doing the work of 25 horses requires approximately the same time in the course of a year as to care for one horse.

Cost of Hauling with Team and Tractor Outfit. The following appeared in *Engineering and Contracting:*

In connection with the construction of an experimental road in 1912 in Sargent Township, Douglas County, Illinois, by the Illinois Highway Commission, a traction engine outfit was used for hauling and placing part of the stone. The road was surfaced with waterbound macadam for a length of 16,800 ft., a width of 10 ft. wide and a depth of 8 in., the haul for the stone being an

average of 3 miles. The rates of pay were: Men, 20 ct. per hour; teams, 40 ct. per hour. The following data on the cost of hauling on this work are abstracted from the recently issued report of the commission:

Cubic yards stone hauled by engine	2,590
Cubic yards stone hauled by team	3,980
Days outfit was on job	120
Days outfit hauled (fraction counted as full)	40
Cost to Illinois Highway Commission of engine operator (salary and expenses, straight time)	$340.00
Cost of fireman (actual time worked)	66.20
Coal, oil and supplies for outfit	181.81
Cost of maintenance of hauling outfit (one-half season).	53.00
Total cost of traction outfit work	$641.01

Total cost per cu. yd. for hauling	$ 0.247
Actual cost per cu. yd. for team hauling (on same work and same length haul)	.560
Cost of hauling by engine, per cu. yd. mile	.082
Cost of hauling by team per cu. yd. mile	.186

Detailed cost of engine hauling:	Per cu. yd.
Operator	$ 0.043
Fireman	.008
Coal, oil, etc.	.024
Maintenance	.007
Total	$ 0.082

SECTION 103

TRAILERS

A small trailer, designed and equipped for use behind an automobile or light truck, is furnished with a spring draw bar, and special hitches for each make of car.

No. 1 trailer has two wheels, a body 78 by 38 inches, 8 in. panel, 5 in. flare board, and drop end gate with chains. It weighs 300 lb., has a capacity of 800 lb., and is priced at $97.50.

No. 2 trailer is similar to No. 1 except that it has no legs. It weighs 290 lb., has a capacity of 800 lb., and is priced at $87.50.

No. 3 trailer has four wheels, a body 96 by 38 in., 10 in. panel, 6 in. flare board and drop end gate with chains. It weighs 500 lb., has a capacity of 1,250 lb., and costs $175.

No. 4 trailer has four wheels, a body 96 by 42 in., 12 in. lower panel, 4 in. upper panel, sides and end removable, a carrying capacity of 1,500 lb., weighs 575 lb., and costs $188.50.

All the above trailers have 1¼ inch solid rubber tires. Prices are f. o. b. Ohio.

Reversible Hauling and Spreading Slow Speed Trailers for use with tractors are as follows:

Slow Speed Reversible Hauling Trailers with stationary platform 11 ft. 10 in. long by 6 ft. wide:

8 inch tires, steel wheels, weight 3855 lb., roller bearings	$610
10 inch tires, steel wheels, weight 4060 lb., roller bearings	635

Extension Trailers similar to above with platform 12 ft. long 5 ft. wide which can be extended to 18 ft. long:

8 inch tires, weight 3910 lb.	$635
10 inch tires, weight 4120 lb.	662

Log Trailer with 12 to 18 ft. wheel base:

8 inch tires, weight 3470 lb.	$860
10 inch tires, weight 3680 lb.	885

Hauling Trailers, bottom dump, capacity 3 cu. yd. level, 3½ yd. rounded load:

8 inch tires, weight 4020 lb.	$625
10 inch tires, weight 4230 lb.	650

Spreading Trailers, bottom dump, similar to the above:

8 inch tires, weight 4125 lb.	$662
10 inch tires, weight 4330 lb.	690

All the above trailers have a capacity of 10,000 lb. and prices are f. o. b. Ohio.

Trailers of one make, f. o. b. Chicago, are as follows:

Reversible Trailers with solid rubber tires, including draw bar and truck hook.

Capacity in tons	Chassis weight	Price Chassis plain	Price Chassis pneumatics	Price Brakes two wheels	Price Per ft. extra up to 5 ft.
1¼	1800	$ 815	$ 975	$105	$ 5.50
2	2200	1100	1225	105	6.00
3	2400	1250	1550	105	6.00
4	3400	1525.	1890	115	8.00
5	3600	1675	2200	115	8.00
7	4000	1875	2650	125	10.00

Drop Frame Reversible Trailer.

Capacity in tons	Dump body cu. yd.	Chassis weight	Price plain	Price with dump body
2	...	2750	$1200	....
3	2½	3150	1325	$1845
3	3½	....	....	1875
4	3	4050	1675	2200
4	5	....	....	2350
6	4½	5100	1875	2500

Road Builder. A four wheel non-reversible trailer equipped with an automatic end dump body. Dump body is removable and can be replaced by flat bed for hauling culvert pipe, lumber, supplies and tools. Extra draw bar fitted to receive wagon tongue in order that trailer can be pulled by horses when required. This may also be used as a semi-trailer.

Capacity tons	Capacity cu. yd.	Weight in lb.	Semi-trailer chassis & dump body	Complete road builder
3½	2½	4600	$1325	$1875
6	4	6700	1550	2100

Semi-Trailer. Single drop-frame type has a low frame less than 24 inches from the ground. Double drop-frame type has a frame equally low in center section only. Prices include a spring actuated rocking fifth wheel.

Capacity in tons	Straight frame chassis	Single drop frame chassis	Double drop frame chassis	Approx. weight
2	$ 495	$ 700	$ 675	1550
3	660	875	825	1700
6	900	1135	1075	2300
10	1425	1750	1650	3200

Pole Trailer.

Capacity in tons	Weight in lb.	Standard construction	Wide-tire (logging)
2	1300	$540	$ 600
4	1700	725	815
6	2000	...	1150
10	2800	...	1475

Fig. 327. Semi-Trailer.

A trailer designed to automatically dump and return, for general construction work, is made so that it may be used as a truck, to collect material and then coupled with one or more ad-

Fig. 328.

ditional trailers to be hauled by a traction engine. It has the following specifications (Fig. 328):

Capacity-weight 6,000 lb., cu. yd. 4.
Roller bearings.
Artillery wooden wheels.
Rubber tires, solid, 36 by 5.
Weight of chassis 3,530 lb.

Weight of body 1,900 lb.
Total weight 5,430 lb.
Price $2,300 f. o. b. New York.

A trailer chassis made in three sizes has the following specifications:

Capacity live load	Body allowance	Weight of chassis	Price
3½ to 5 tons	1500 lb.	4083 lb.	$1925
2 to 3 tons	1200 lb.	2565 lb.	1300
1½ to 1 ton	500 lb.	1395 lb.	875

The above prices are for the chassis only. A number of dump and other type bodies are to be had for these trailers.

A 3 yd. steel bottom dump body costs $590. A 2½ yd. body costs $515.

Comparison of Cost of Operating Motor Trucks and Trailers. The following costs, given by a manufacturer of trailers, are estimated and are stated to be conservative.

COST OF OPERATING A 5-TON TRUCK

Average cost of 5 ton chassis	$5,000.00
Rear dump body and hoist	625.00
Interest on investment, 6%	337.50
Insurance, liability, fire, collision, property damage	295.00
Driver's salary, at $5 per day, 300 days	1,500.00
Garage	180.00
License	25.00
Fixed charges per year	$2,337 50
Fixed charges per day (300 day year)	7.79

Variable charges	Per mile
Tires	$ 0.0787
Gasoline, 4 miles per gal. at 27 cents	.0675
Lubrication, oils and grease	.0030
Repairs, maintenance and overhauling every 150,000 miles for $500	.0330
Depreciation	.0328
Variable charge per mile	$ .2150

Applying this expense against the total daily capacity of the truck, we will take for example a 5-mile haul. It is safe to assume that the truck will make at least 5 trips per day of 5 miles each way, or 10 miles round trip, making a total distance of fifty miles. This is the lowest minimum capacity, and the truck should have no difficulty in making this as a yearly average.

The fixed charge per day is $7.79. The variable charge is .215 per mile or for 50 miles $10.75, which makes a total charge for the day, including the fixed charge, $18.54. Five tons per trip would make 25 tons hauled a distance of 5 miles during the day, or 125 ton-miles at a cost of .148 per ton-mile or .74 per ton for hauling it 5 miles.

Cost of Operating a 5-Ton Trailer

Cost of 5 ton trailer	$1,925.00
3 yd. steel bottom dump body	590.00
Interest on investment at 6%	150.90
Garage	60.00
License	25.00
Helper, $3.00 per day, 300 days	900.00
Insurance, fire and liability	75.00
Fixed charges per year	1,210.90
Fixed charges per day (300 day year)	4.07

Variable charges	Per mile
Tires	$ 0.064
Lubrication	.0006
10% additional gasoline for truck	.0067
Repairs and maintenance, $100 per year	.0066
Depreciation	.0059
Variable charge per mile	$ .0838

Combining the operating cost of the truck at $18.54 with the total cost of the trailer at $8.26 would make a total operating cost of $26.80 instead of $18.54 for the truck alone, or about 20% additional for the trailer. With the 2% increase in operating cost, the efficiency of the entire unit would be increased 100%, for the truck would not have any difficulty in making the same number of trips with the double load or 10 tons, consequently 50 tons could be hauled per day a distance of 5 miles, with a total cost of $26.80 or .1079 per ton mile, as against .148 with truck alone, or .536 per ton as against .74 by truck, or a total saving for hauling 50 tons of $10.12.

Trailers of another make cost as follows:

Bottom Dump Trailers (reversible) with steel wheels.

Capacity	Weight	Price
3 cu. yd.	3620	$505
4 cu. yd.	3740	525

Spreading Trailers (reversible) with steel wheels.

3 cu. yd.	3825	$575
4 cu. yd.	3950	595

Logging Trailer. Rated at 5 tons, reversible, with four wheels turning at the same time weighs approximately 3,450 lb., and costs with 6 in. steel wheels $575, and with 8 in. wheels $600. This trailer can be furnished on order for 10 ton capacity at an extra cost of $150.

One Way Dump Trailer costs $350. It weighs approximately 2,400 lb.

Tractor hitch on slow moving trailers	$15
Couplings for tractors, per pair	12

Crushed Stone Spreader, with rubber tires:

1½ yd. capacity	$ 875
2½ yd. capacity	1465
3½ yd. capacity	1500

Trailer Chassis

4 steel wheels

Capacity	Weight	Price
3 ton	2750	$1125
5 ton	3840	1290

Semi-Trailer Chassis, two wheel type with rubber tires, are made in three sizes: 2 ton $450, 4 ton $725, and 6 ton $800.

Bottom Dump Semi-Trailer with two wooden wheels are made in two sizes. The 2 yd. capacity costs $250, the 3 yd. $300.

Trailer Bodies

Kind	Size	Price
Express with flare	6 by 14 ft.	$240
Express with flare	5 by 12 ft.	210
Side dump with apex	105 cu. ft.	400
Side dump with apex	72 cu. ft.	350
Stake body	6 by 14 ft.	180
Stake body	5 by 12 ft.	140

SECTION 104

TRANSITS

A low priced and yet reliable transit, known as a builder's transit, weighs 6 lb., and costs $105

Surveyor's transits with a 5 in. needle weigh 16½ lb., and cost $280.

An engineer's transit with an 11½ inch telescope, weight with tripod about 24 lb., price in box $250. Same with stadia circle, $265.

A preliminary survey transit with an 8 inch telescope, weight with tripod about 16 lb., price complete $150. Patent extension tripod $7 50 extra.

A stadia hand transit with 10 inch telescope, weight in case 2½ lb., price $40. With micrometer leveling attachment $3.50 extra.

A pocket transit of aluminum costs $25.

SECTION 105

TRENCHING MACHINES

The term Trench Machine comprises machines of many varied types, such as cableways on which are operated buckets, steam shovels with booms and buckets especially designed, and elevator bucket machines.

A Cableway can be used to advantage on trenches 8 feet and wider. The main cable is stretched on towers 30 feet high and three to four hundred feet apart. One tub of one cubic yard capacity is handled at a time and can be loaded at any point and swung as much as 10 feet to one side. The cable machine is advantageous in soft digging or on rock as no part of the machine is carried by the side banks. The engine and one tower stand on a car which runs on tee rails; the other tower stands on the ground and must be lowered and carried to a new position. The outfit can be loaded on one car and weighs about 19 tons; price of cableway from 250 to 400 ft. is from $5,500 to $6,000. According to the manufacturer, from 15 to 20 trips may be made per hr. under ordinary conditions. General repairs are such as are necessary on any contractor's hoisting engine in constant use, together with the replacing of worn out steel ropes and running parts, which are comparatively small items, as there are no parts subject to frequent breakages as in the case of steam shovels and ditch digging machines.

These cableways are usually driven by an 8¼ by 10 double cylinder engine capable of lifting 5,000 lb. They raise the buckets at a speed of about 225 ft. per min. and transport them at a speed of from 500 to 600 ft. per min.

Mr. James Pilkington, of New York, says that he has taken the machine down, moved 250 ft. and put it up again in three hours and fifty minutes.

A self-propelling machine for excavating small trenches and which digs by means of scrapers and buckets fastened at the rim of a revolving wheel is said by the manufacturer to be able to excavate in any ground that can be loosened with a pick. The machine will cut through a log or timber, but if it strikes

a large boulder the wheel must be raised out of the trench until the obstruction is passed.

These machines are operated by gasoline engines and cost as follows:

Hp.	Max. depth	Max. width	Cutting speed ft. per min.	Approx. weight	Price
20	5½′	14½″	2½ to 9	13,500	$2,700
25	5½′	18″	2 to 6½	17,600	4,200
30	6½′	18″	2 to 6½	19,600	4,700
40	6½′	24″	1¾ to 6	26,000	6,100

Cost of Trenching in Shale with Wheel Type Excavator. The following appeared in *Engineering News-Record* Feb. 14, 1918. Four miles of 6- and 12-in. water-main trenches in wooded or frozen ground and with shale at the bottom were completed with a machine by the Water Department of Erie, Penn., between Feb. 1 and Oct. 5, 1917, at a cost far below that of hand work, even in 1915. Though at the speed developed by the machine, 3 to 3⅔ ft. per minute on 5½- and 6-ft.-deep trenches, this represents less than two weeks' steady work, the difference in the amount paid for hand labor per foot in 1916 and in the cost per foot of all labor and fuel required with the machine represents more than half the first cost of the tool saved on the four miles already completed. The saving is still greater, if the advance in wages since 1916 is considered, but in spite of it the increased labor cost of laying pipe and backfilling will make this year's work somewhat more expensive per foot than that done in 1915 or last year. Nevertheless, it is doubtful if the extensions built in 1917, representing more work than was done in either of the preceding years, could have been completed without the machine because of the scarcity of labor.

The trenching machine, bought early this year for $5,650 f. o. b. Erie, is of the wheel type. The buckets are adjustable for cutting 24 to 28 in. wide and trenches 7½ to 11 ft. deep can be dug. The machine is driven by a four-cylinder, four-cycle, 45-hp, gasoline engine. Ordinarily, one operator and one helper run it without other assistance under the supervision of the foreman who looks after the rest of the work. The trenches cut are 2 ft. in width and from 5½ to 6 ft. in depth. Clay 2 to 4 ft. deep, underlain by the shale shown in the photograph, is encountered on nearly all the work, though one trench has been dug in running gravel. Conditions are such that the machine cuts full length for the extension to be laid in a continuous operation, most of the trenches being less than 2,000 ft long. The pipe gang of seven men lays the new main behind it at the rate of a block, or 660 ft., a day. As the water mains are always extended in advance of paving,

operations are completed by backfilling the trench with a team and scraper. In this manner 1½ miles of 12-in. and 2½ miles of 6-in. pipe were laid between Feb. 1 and Oct. 5 last.

During 1915, considered an ordinary year, the city laid 25,000 ft. of 6- and 12-in. mains in hand excavated trenches at a labor cost for digging, laying and backfilling of 28.8c a foot for the smaller and 36.08c. a foot for the larger size Much more pipe was laid in 1916 and this year because of the rapid growth of the city. While complete unit costs for the last year's work have not yet been compiled, it is known that rising wages caused considerable increase over those of 1915. Records for 10,000 ft. of 6-in. main laid at one time last year show a total labor cost of 37.1c. per foot of which digging alone represented 19c. with common labor 27½c. an hour. The trench was in clay, with shale at the bottom. As compared with this, the first performance with the trenching machine, excavating for 1620 ft. of line, was accomplished at a fuel and labor cost of $132.84, or 8.2c. per foot for actual digging. This was in gravel which required sheeting, the cost of which is included in the above figure. On another occasion, in digging through cut-over land, where many large but partly rotted stumps were cut through, 682 ft. of trench was dug in four hours, at a cost of $7.55 for three men and 15 gal. of gasoline — only 1.1c per foot. On Oct 5 the machine made its speed record of 660 ft in three hours, but $3.02 for gasoline and $1.88 for the wages of the engineer and helper being charged to the operation. This was about ¾ of a cent per foot. Both trenches were in shale at the bottom.

That these costs are typical of the work is shown by the record which the machine made on its most difficult bit of digging. Last winter, with 18 in. of ground frozen hard, it dug in one operation 7,220 ft. of 2 x 5½-ft. trench at an average speed of 3 ft. per minute. But this is not all. The bottom of that trench was in shale, the average depth of which proved to be 44 in. Over most of the trench the clay was frozen to the top of the shale.

This shale is not laminated clay, but a true shale, which can be picked in excavating bell holes, but which it pays to shoot when any considerable yardage must be removed by hand.

The two miles of trench dug in these four operations are typical of the machine's work to date. It shows no appreciable wear, and maintenance on it has been negligible. The trenching in question, if done at the unit cost of the 2-mile trench dug by hand in 1916, would have represented a labor charge of $1,935, whereas it actually cost, for labor and fuel, $200, fully half of which was chargeable to the sheeting required on the first gravel trench dug. This represents a saving of $1,735. Doubling this for the four

miles of main dug to Oct. 5, the machine appears to have saved $3,470, or to have more than half paid for itself.

Methods Employed in Constructing Concrete Pipe Sewer in Jackson, Mich.* Special methods and devices for trenching and pipe laying have been employed in constructing two lock joint concrete pipe trench sewers in Jackson, Mich. These sewers vary in diameter from 4 ft. to 18 in., and each is about 2 miles long, and the lock joint concrete pipe is used for 24 in. in diameter and above, vitrified pipe being used for the 18-in. line.

The trench is largely through sand and gravel and considerable water and running sand were encountered. The depth ran from 7 ft. to 25 ft. and tight sheeting was required throughout. The first few feet of cut were made with horse and scraper; if the trench did not exceed 8 ft. in depth the deepening was continued by hand; for depths exceeding 8 ft. a trench machine was used. The sheeting was driven by hand and was pulled after the trench had been nearly refilled by means of a chain block fastened overhead to a rail laid on the bents of the trench machine. Two men pulled all the sheeting.

The trench machine is shown by Fig. 329. It was designed by City Engineer A. W. D. Hall, and, built 150 ft. long, cost $500, including three ½ cu. yd. self-dumping buckets. The construction calls for very little explanation. As will be seen, the whole machine is made so as to move along the work on track rails laid on the banks of the trench. An ordinary double drum hoisting engine operates the traveler, one drum giving the traveling movement and the other drum doing the hoisting. The usual method of operation was employed. The excavated spoil was raised in the buckets, conveyed back and back-filled onto the pipe, which had been laid as fast as the trench was opened.

When water was encountered in the trench it was handled as shown by the sketch, Fig. 330. The force pipe of an ejector, shown in enlarged detail by Fig. 330, was attached by hose to the nearest hydrant, which gave the ordinary domestic pressure of about 60 lb.; the suction pipe with strainer end drew from the trench sump and the discharge pipe passed over a bulkhead into the completed sewer.

In pipe laying the usual methods were followed, the pipes being rolled onto skids over the trench and lowered by the trench machine. The pipe laying was straightforward work except where running sand or quicksand was encountered and then the special shield shown by Fig. 331 was employed. This shield consists, as will be seen, of three sides of a bottomless box. It is operated

* *Engineering-Contracting*. Nov. 10, 1909.

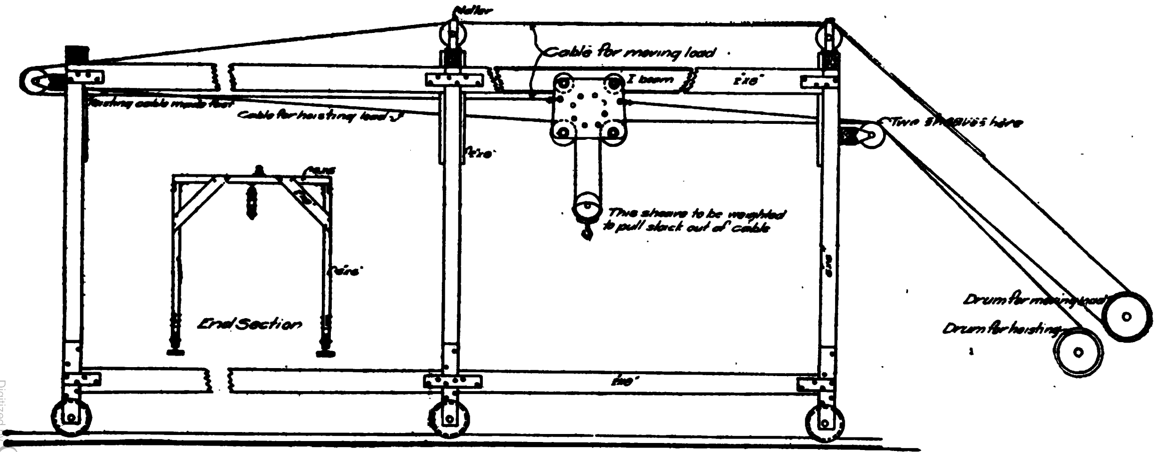


Fig. 329. General Details of Trench Machine Used on Sewer Work, Jackson, Mich.

as follows: When near grade the shield is set on the trenc bottom in the position illustrated, with its open end straddling th end of the completed pipe. Hay is then stuffed into the space

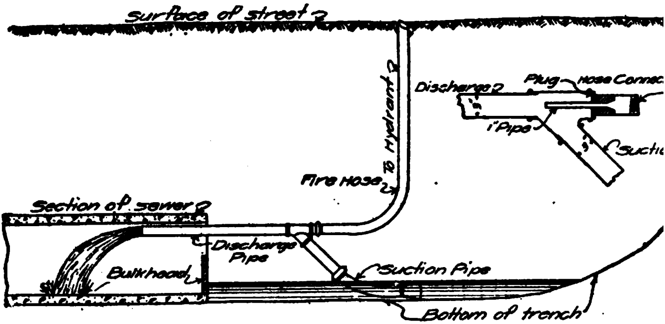


Fig. 330. Sketch Showing Ejector and Method of Pumping Wat from Sewer Trench.

between the sides of the pipe and the sides of the shield to kee the mud out and two men inside the shield excavate down t

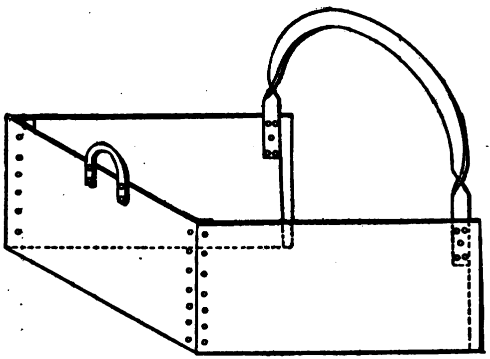


Fig. 331. Sketch Showing Steel Plate Shield Employed in Layin Sewer Pipe.

grade, driving down the shield as they sink the excavation. Whe the excavation is completed the pipe is laid and jointed insid the shield, which meanwhile acts as a temporary cofferdam.

Only general figures are available on the cost of this work. Mr. Hall states that for depths of 10 ft. and less the cost has varied so much owing to local conditions, differences in material, etc., that it is impossible to get at average costs. He states that the cost of excavating 42-in. sewer from 17 to 20 ft. deep has been 53 ct. per cu. yd. The trench at 17½ ft. depth contains 4.7 cu. yd. of excavation per lineal foot and costs $2.50 per lin. ft. At a depth of 26 ft. the trench contains 7.05 cu. yd. of excavation and costs 75 ct. per cu. yd., or $5.28 per lin. ft. of trench. Between 17 ft. and 26 ft. depth the costs vary about in proportion from 53 ct. to 75 ct. per cu yd. These costs include excavation, back filling, driving and pulling sheeting, pipe laying and cleaning up and grading the street after the work. They include everything except cost of pipe and cost of sheeting timber and, apparently, plant and overhead charges. The gang worked consists of 30 men; common labor is paid $2 to $2.25 per day, enginemen $3 per day and foremen $5 per day. The work is being done wholly by day labor. The information from which this article has been prepared has been furnished by Mr. Hall.

Another type of self-propelling trench excavator can attain a road speed of 2½ miles per hour. The earth is excavated by buckets traveling on a chain elevator and is removed to the side of the trench on a belt conveyor. The buckets are self-cleaning and travel across the face of the trench in order to excavate to the proper width which is regulated by two set screws. It is not necessary to change the buckets or scrapers to change the width of the trench. The manufacturers rate their machines at ¾ cu. yd. per minute. The machine is operated by one man; coal consumption 1,200 to 2,000 lb. per 10 hours. The weight of the machine is well ahead of the trench. It is not suited for very rocky ground, but when a large boulder or similar obstacle is met the buckets can be raised over the obstruction and can start again on the farther side of the obstruction.

STEAM DRIVEN TRENCHERS

Trench widths in inches	Max. depth in ft.	Traction	Approximate weight in lb.	Price f. o. b. Iowa
18 to 36	15	caterpillar	33,000	$10,600
24 to 48	18	caterpillar	50,000	12,800
28 to 60	20	caterpillar	54,000	12,300
28 to 60	20	wheel	48,000	11,200
28 to 78	24	caterpillar	58,000	13,400
28 to 78	24	wheel	52,000	12,300
		GASOLINE DRIVEN		
15 to 24	10	caterpillar	17,000	7,200

Oil Driven

18 to 36	15	caterpillar	30,000	9,600
24 to 48	18	caterpillar	45,000	11,900

Excavators of the self-propelling type, in which the earth is excavated by scrapers and buckets traveling on a chain elevator and removed to either side of the trench on a belt conveyor, are shown in the following table.

Steam Driven

Hp.	Max. depth	Max. width	Max. digging speed per min.	Trac. speed per hr.	Approx. weight	Price
20	10′	29″	10′	2½	31,000	$ 8350
20	10′	42″	10′	2½	33,000	9200
25	15′	40″	10′	1½	54,000	9800
30	18′	40″	6′	1¼	63,000	13500
30	18′	52″	6′	1¼	75,000	15000
40	18′	72″	3′	1	106,000	18000

Gasoline Driven

18	6′	23″	10′	1½	18,000	7200
36	10′	29″	10′	2½	30,000	8350
36	10′	42″	10′	2½	33,000	9200
50	15′	40″	10′	1½	53,000	9800
75	18′	40″	6′	1¼	65,000	13500
75	18′	52″	6′	1¼	77,000	15000

The manufacturers say that the machine will probably need no repairs for one year; then the repairs on the smaller machines will be from $1 to $2 per day, on the larger machines from $2 to $5 per day. They are regularly fitted with caterpillar traction on the digging end and wheels on the other.

Progress Diagram and Distribution of Time of Force on Sewer Trenching by Machine. After W. G. Kirchoffer. Recently an 8-in. sewer 5,270 ft. in length was laid at West Salem, Wis. The excavation was made in a sandy gravelly clay by the use of a Parsons' trenching machine. The trench averaged about 8 ft. deep. The total number of days' work put in on the job was 325¾, or an average of 61.8 days per 1,000 ft. of sewer. The trenching machine was operated 20 days out of the total 26 put in upon the work, or an average of 263½ ft. per day. The least distance made in a day was 20 ft. and the maximum distance was 550 ft. of completed sewer. There were five days in which the rate exceeded 400 ft. of sewer per day. The progress diagram is shown in Fig. 332.

The labor upon the work was divided as follows in days per 1,000 ft. of sewer:

Contractor	1.092
Inspector	4.935

Pipe layer	4.315
Foreman	4.270
Engineer	4.79
Fireman	4.412
Team	3 417
Mason	3.75
Water boy	1.993
Common labor	26.04
Tamper	4.13

The greatest number of men employed in any one day was 16 and the smallest number was two.

This work was done under the supervision of W. G. Kirchoffer, consulting engineer, Madison, Wis. The contractor was F. E. Kaminski of Watertown, Wis.

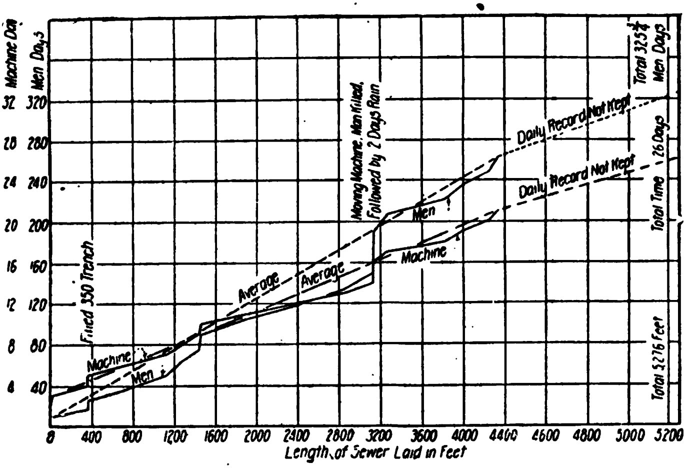


Fig. 332. Progress Diagram of Sewer Trenching Machine at West Salem, Wis.

Trenching by Machine for a 36-in. Brick Sewer.* An interesting example of machine trenching under favorable conditions of soil is furnished by the sewerage of an area of about 30 square blocks south of 80th St. and east of Aberdeen St., in Chicago, Ill. The sewers to be built comprise about 665 ft. of 36-in. brick sewer, about 2,200 ft. of 30-in. brick sewer and some 17,000 ft. of 15 and 18-in. pipe sewer. The depth of these sewers below natural ground surface is an average of 14 ft. The soil consists of black loam overlying yellow and blue clay, the clay being stiff enough

* *Engineering and Contracting*, July 17, 1912.

to stand well with only occasional sheeting planks. Altogether the soil conditions are well fitted for trenching by machine and all trenching is planned to be done by machine. The machine used was a No. 1 Austin Trench Excavator fitted with buckets cutting to a depth of 42 inches.

The work at present is on the 36-in. circular sewer, which consists of a two-ring invert and a single ring arch. Following the machine the trench bottom is troughed to templets of the sewer inverts. For this larger sewer the trench sides were to be under-

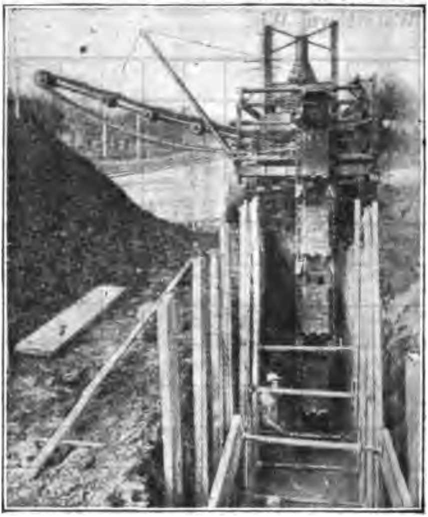


Fig. 333. Excavating Trench for Sewers Seventy-Eight Inches Wide and Twenty Feet Deep at Des Moines, Iowa.

cut at the bottom, since the excavator cuts only 42 in. wide, but with the smaller sewers there will not be this extra work. Three men pick the bottom and undercut the sides behind the excavator, which is kept about 15 ft. ahead of the invert masons. Vertical plank spaced about 2 ft. apart and bound with pipe and iron bands are sufficient to keep the trench sides safe.

Three bricklayers work on the inverts and two work on the crown which follows from 30 to 50 ft. behind. Brick handlers, mortar men and helpers bring the force on brick work up to 30 men. The invert brick are laid to the templet cut trench

bottom. To undercut the arch flat iron circles in two parts connected by bolts are set 6 ft. apart on the completed inverts and 2 x 4 in. lagging is laid on them to form the arch center. The rings are collapsed by removing the connecting bolts.

Trench excavation was begun June 3 and at the time the work was visited, July 8, 1,600 ft. had been excavated. This, however, is no indication of the speed of the excavator, for it is worked only fast enough to keep some 15 ft ahead of the invert masonry. On two favorable days, 184 ft. and 170 ft. of sewer were built, but the average advance has been much less. The contractor stated that the machine had not worked over half the time.

An estimate of the cost of operating the excavator based partly on assumed progress, is as follows:

Engineer	$ 5.00
Fireman	2.50
Coal	4.00
Oil and waste	.50
Repairs	1.00
Depreciation	2.73
Interest at 5%	1.37
Total cost per working day	$17.10

The machine will use about three-quarters ton of coal per day. To be conservative we have assumed one ton at $4.00. The repairs were also estimated at $1.00 which is considered liberal. The depreciation is taken at 300 days' work per year for ten years, and although it is assumed that the owner of such a machine will be able to sell it at the end of that time, no allowance for salvage value is made here.

Assuming that the brick sewer may follow the machine at a rate of 170 ft. per day, the cost per foot of trench excavation is 10 cents, or 5 cents per cu. yd. If the contractor could double the rate of brick construction he could then reduce the excavation cost by one-half, as he states that the machine is used about 50% of the time. Other items enter into the increase in speed of brick sewer construction which might increase the cost of that part of the work more than the reduction in cost of excavation. The decrease in cost of excavation on the 3,000 ft of brick sewer if built at twice the rate of speed would be 3,000 × 5 cents, or $150, which is hardly enough to warrant the risk of increasing the cost of the brick work.

Figs. 334–335 illustrate well known trenching machines on various types of construction.

Method of Thawing Ground for Trenching. The following appeared in *Engineering News*, Feb. 18, 1915, by Mr. A. Lenderink.

For the purpose of assisting the unemployed, the common coun-

cil of Kalamazoo, Mich., decided to build during the winter some of the sewers that were planned to be built during the coming summer.

Fig. 334. Carson Trench Machine Purchased by City of Brandon, Manitoba, Canada, and in Use on First Street Sewer. Hoists Six Tubs at a Time.

Fig. 335. Carson-Lidgerwood Cableway on Work of Bramley & Gribben, Walworth Run Sewer, Cleveland, O.

The ground in the streets was frozen 18 to 24 in. deep. The engineering department decided to try steam as a means of removing part of the frost so that it would be easier for the men and also keep the cost of the excavation from becoming too

great. The department has a 10-hp. upright boiler and engine mounted on a truck so that it can be easily moved about. A 1-in. steam line from the boiler was laid along one of the outer edges of the proposed trench for a distance of 100 to 150 ft. from the boiler and returned along the other edge. The part of the trench was then covered with some wooden sewer forms that the city used for large concrete sewer construction, and the forms covered with 6 to 8 in. of sand. The pipes were kept off the ground by a few bricks.

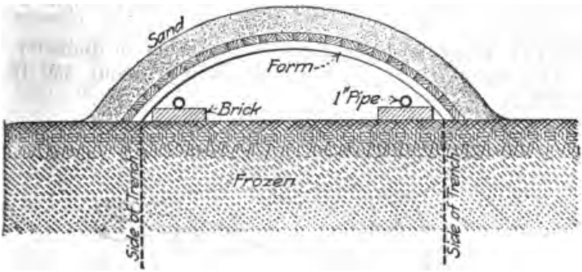


Fig. 336. Cover and Steam Pipes for Thawing Ground.

It was found that by keeping steam on the pipe for 24 hr. the frost in the part under cover was entirely removed. The moisture in the thawed ground allowed the men to shovel the top dirt out of the trench without using a pick to loosen it.

The pipes and forms were moved ahead each morning and the thawing started for the next day's work, a portable shelter being built around the boiler.

The cost of the thawing, for a trench 3 ft. wide, was 8 to 10c. per lin. ft., exclusive of interest and depreciation on the boiler.

TRUCKS

Pole Truck for moving heavy material has a frame 42 by 27 inches, wheels 30 inches in diameter, 3-inch face, weighs 300 lb., price $57.50.

Tramway Truck with steel wheels 36 inches in diameter, 6 ft. 6 in. long by 3 ft. 2½ inches wide, weighs about 350 lb. and costs $46.

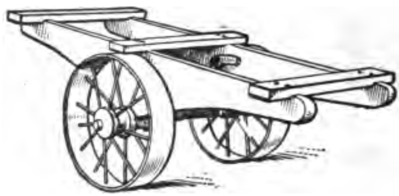


Fig. 337. Timber Truck.

Timber Truck used extensively by builders for handling heavy beams and timbers. Size 6 ft. 4 in. long, 2 ft. 7 in. wide, wheels 2 ft. in dia. 5 in. wide, price $52.50.

Two Horse Trucks cost about as follows:

Capacity in tons	Approximate weight in lb.	Price
2¼	2000	$250
2½	2300	275
4	3500	350

Stone Truck for handling heavy stone, designed so that a stone can be rolled on the lower end without lifting, has two wheels diameter 18 inches. tread 2½ inches, width of truck 18 inches length 9 ft. Price $27.50.

SECTION 107

UNLOADING MACHINES

Unloader plows, Figs. 338, 339, are largely used in railroad and canal construction. The best types are constructed entirely of steel. They are usually operated by being pulled through the train of cars by a cable attached to the engine. Three types

Fig. 338. Side Plow.

are manufactured: the center unloader, which distributes the material equally on both sides of the track; the right unloader, which distributes the material to the right; and the similarly constructed left unloader, which places the material on the left.

Center Plows

Capacity of cars, cu. yd.	Height of mouldboard, in.	Weight in lb.	Price f. o. b. factory
10	38	6,100	$1100
10 to 20	45	7,000	1275
20 to 35	58	9,400	1675
35 to 40	60	13,400	1975

Side Plows, Left or Right

10 to 20	42	4,750	$ 675
20 to 35	58	7,500	1050
35 to 40	66	9,200	1225

Fig. 339. Bucyrus Left Hand Side Plow at Work on Erie Railroad.

The time occupied in unloading a train of 12 cars with an unloader plow is from 10 to 30 minutes, the engine doing as much in that time as 8 to 10 men would do in a day. When unloading on curves the time is longer, for snatch blocks must be used to keep the cable on the cars. A snatch block every third car is generally enough. When the plow reaches a snatch block it must be stopped, the block and chain being removed and carried forward. Unloading in this way takes about twice as long as on straight track and often longer.

When much material is to be handled the cars should be rigged with hinged side boards that can be dropped down when unloading, and a hoisting engine should be rigged up on a car by itself for

the purpose of pulling the plow cable. A 10 x 12 in. double cylinder engine with a 1-in. cable for loose gravel, and a 1⅛-in. for heavier material will unload a train of cars often in half the time taken by locomotives, since the cars need not be blocked, and the danger of breaking the cable is decreased.

The cost of repairs to unloading plows on the Panama canal work during the 6 months ending June 30, 1910, was for 1,655 days of service, an average of $3.79 per day per plow.

Mr. H. R. Postle in an article in *Engineering-Contracting* of October 12, 1910, describes a device constructed by him for unloading crushed stone from railroad cars into dump wagons. By the old method of shoveling, unloading crushed rock ordinarily costs from 20 to 25 cents per ton, with California wages, but by means of this apparatus rock is being unloaded for about one-third to one-half of this amount. The method is to draw the rock over the end of the car through a chute hung to the end of the car and into the wagon by means of an ordinary slip scraper (largest size), to which is attached a ⅝-in. wire cable, connected to hoisting drum, operated by a gasoline engine.

The chute is built of 2-in. lumber and is 6 ft. wide at one end, 5 ft. at the other end and 5 ft. long and is supported by two legs so that it just clears the wagons, allowing them to be driven under or moved ahead. A roller 3 or 4 in. in diameter is mounted on the outer end over which runs the cable drawing the scraper and against which the scraper falls when dumping. The hoist drum and gas engine are mounted on a low truck so as to be easily moved. The engine is a 10-horsepower gas engine belted to the hoist drum with an 8-in. belt. The hoist drum is 12 in. in diameter and 10 in. wide.

Cars are spotted with the aid of the hoist and the loading is always done at the same spot, as the cars are thus moved more quickly than the apparatus could be moved from car to car.

The cost of this equipment was as follows:

Gas engine, 10 hp.	$350.00
Hoist drum	125.00
Truck	50.00
Large scraper	10.00
125 ft. of cable	9.00
Pulley block	3.00
Chute (estimated)	5.00
Total	$552.00

Machine for Loading from Cars or Stock Piles into Wagons. Fig. 340 illustrates this machine which is a self-contained bucket elevator. It is used in unloading coal, sand, gravel, broken stone, etc., from cars to wagon or stock pile or to loading from stock

pile to wagons or cars. The bucket elevator is about 14 ft. long and is held in a steel casing which also holds an operating motor, a hoisting winch and a connection for a discharge spout. In operation the casing is suspended from a derrick, or, it may be, from any yard arm, boom or fall block convenient, and is lowered into the car or stock pile feeding down by its own weight as the

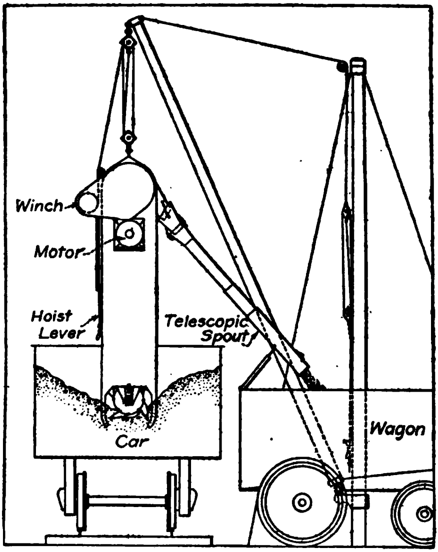


Fig. 340. Portable Car Unloader.

material is taken out. The operation is made clear by the drawing. To operate the elevator only one man is required to swing the device about and raise or lower it so as to keep it fed with material. When not in use the elevator is raised up to the boom end and swung clear of cars or other plant in whose way it may be. All parts of the elevator are made of steel. It weighs approximately 7 tons and costs $5,500 f. o. b. New York.

SECTION 108

WAGONS

Dump Wagons. Dump wagons of one make cost as follows:

Capacity in cu. yd.	Weight in lb.	Price f. o. b. factory
1½	1850	$220
2	1900	228

Additional for equipping with brake	$15.00
Additional for lining doors with steel	6.50
Additional for lining body and doors	20.00

Dump Boxes for above wagons are made in two sizes: the 1½-yd. size costs $66.50; the 2-yd. size, $74.50.

Bottom dump wagons of another make cost as follows:

Capacity cu. yd.	Capacity lb.	Weight in lb.	Price f. o. b. New York
1	6,500	2,270	$220
1½	6,500	2,300	225
2	6,500	2,320	230
2½	6,500	2,350	235

Extra for brake, side or rear	$15
Extra for separate top box, ½ yd.	10
Extra for separate top box, 1 yd.	18

With reasonable use a wagon will last five years. Wagons are usually sold under a six months' guarantee.

For heavy loads tires should be ⅝-in. thick. The difference in cost between a ½-in. and ⅜-in. tire is about $5.00 and the saving in wear and tear is many times this.

Old wagons for a period of twelve months averaged for repairs $3 per month. Original cost $70. New wagons other than dump wagons, original cost $150, averaged $2 for repairs for eighteen months.

Wagon Poles of oak, non-ironed, cost about $7.00 each. It takes a man about one hour and a half to fit a pole. On rough work a wagon pole lasts about two months; if used on fairly good roads it should last two or three years.

The following data are from a report made by the Construction Service Co. of New York on the economic performance of Re-

versible Dump Wagons of three yards capacity drawn by traction engines as compared with ordinary two-horse 1½-yd. wagons.

The assumed value of the traction drawn plant is as follows:

Item	Value	Life	Dep. rate per year	Dep. per working day	Int. per working day
12 — 3 yd. wagons ..	$2,724.72	6 years	16⅔%	$2.60	$0.93
Engine	2,000.00	15 years	6⅔%	.76	.69
Water tank	300.00	10 years	10 %	.17	.10

The standard cost of operating the same with traction engine is:

Engineer	$ 3.00
Fireman	2.00
Coal for 10 miles, average 1¼ tons, at $2.25	2.82
Repairs	4.30
Depreciation	3.53
Interest	1.72
Liability insurance, say 2% of the payroll	.13
Miscellaneous and superintendence, 20% of the above	3.50
Total expenses per day	$21.00

The assumed value of a horse is $150 and the assumed cost of operating the horse-drawn plant is as follows:

Two horses cost, per day	$3.00
$110.00 wagon, depreciation	.124
Interest	.044
Repairs	.15
Miscellaneous, including harness, etc.	.072
Driver	1.50
Insurance, 2% of payroll	.03
Miscellaneous and superintendence, 20%	.98
Total expense per day	$5.90

The assumed working season for the traction-drawn outfit is 7 months of 25 working days or 175 working days per year, whereas, the assumed season of the horse-drawn outfit is 7½ months of 20 working days or 150 working days per year.

The accompanying diagram gives the resultant unit costs for different loads and length of haul.

The following table which gives the cost of hauling of various materials in wagons is taken from *Engineering & Contracting*. The average net load is assumed as 3,000 lb., or 1½ short tons. A good team can readily haul such a load over fair earth roads. An average traveling speed of 2½ miles per hour going loaded and returning empty at a rate of 3½ per 10-hour day for team and driver is assumed. The cost of hauling 1 mile does not include the cost of loading and unloading.

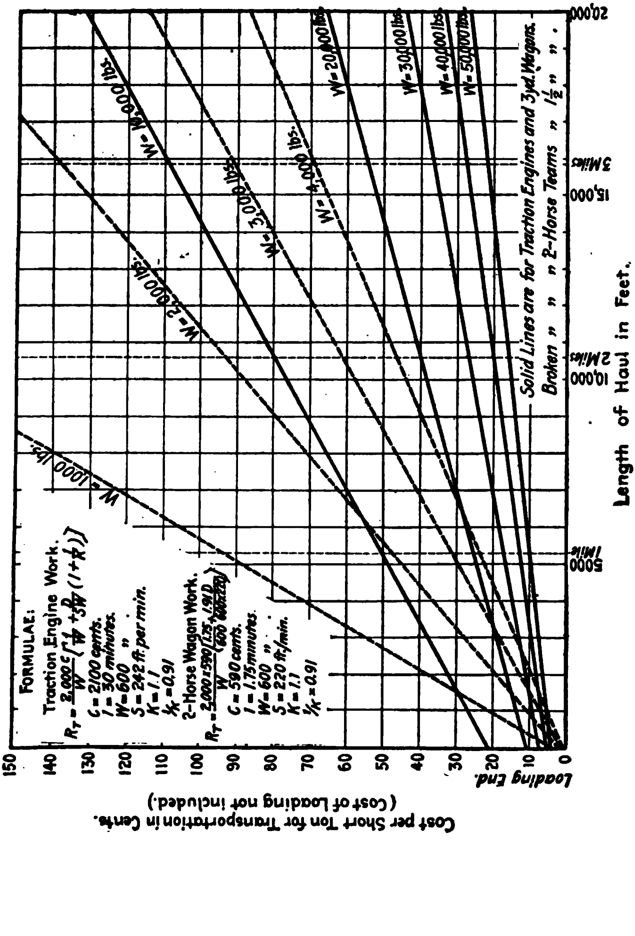

FORMULAE:
Traction Engine Work.
C = 2100 cents.
l = 30 minutes.
W = 600 "
S = 242 ft. per min.
K = 1.1
1/K = 0.91
2-Horse Wagon Work.
C = 590 cents.
l = 1.75 minutes.
W = 600 "
S = 220 ft./min.
K = 1.1
1/K = 0.91
W = 1000 lbs.
W = 2,000 lbs.
W = 3,000 lbs.
W = 4,000 lbs.
W = 20,000 lbs.
W = 30,000 lbs.
W = 40,000 lbs.
W = 50,000 lbs.
Solid Lines are for Traction Engines and 3 yd. Wagons.
Broken " " " 2-Horse Teams " 1½ " "
5000 1 Mile
10,000 2 Miles
15,000 3 Miles
20,000
Length of Haul in Feet.
Cost per Short Ton for Transportation in Cents.
(Cost of Loading not included.)
Loading End.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

Fig. 341.

Material	•Load (3000 lb.)	Cost of haul, 1 mile, ct.
Brick, building (2¼ x 8¼)	555	50 per M.
Brick, paving (2½ x 8½ x 4)	444	63 per M.
Block, paving (3¼ x 8½ x 4)	333	31 per M.
Broken sandstone	1.2 cu. yd.	23 per cu. yd.
Broken trap rock	1.1 cu. yd.	25 per cu. yd.
Cement, natural	11 bbl.	2.5 per bbl.
Cement, Portland	7½ bbl.	3.7 per bbl.
Coal	1½ tons	18.6 per ton
Earth	1.2 cu. yd.	23 per cu. yd.
Lime	14 bbl.	2 per bbl.
Rock, granite, solid	0.66 cu. yd.	42 per cu. yd.
Sand, dry	1.1 cu. yd.	25 per cu. yd.
Sewer pipe:		
4 in.	332 lin. ft.	0.084 per lin. ft.
6 in.	200 lin. ft.	0.14 per lin. ft.
8 in.	40 lin. ft.	0.7 per lin. ft.
12 in.	140 lin. ft.	0.2 per lin. ft.
18 in.	66 lin. ft.	0.42 per lin. ft.
Tile, 4 in.	428 lin. ft.	0.065 per lin. ft.
Timber:		
Kiln dried oak	800 ft. B. M.	35 per M. ft.
Kiln dried yellow pine	1000 ft. B. M.	28 per M. ft.
Southern yellow pine, green	666 ft. B. M.	42 per M. ft.
White oak, green	600 ft. B. M.	46 per M. ft.
Water	48 cu. ft.	58 per 100 cu. ft.
Water	360 gal.	0.077 per 100 gal.
Water pipe (cast):		
4 in.	132 lin. ft.	0.21 per lin. ft.
6 in.	84 lin. ft.	0.33 per lin. ft.
8 in.	60 lin. ft.	0.47 per lin. ft.
12 in.	36 lin. ft.	0.77 per lin. ft.
20 in.	12 lin. ft.	2.3 per lin. ft.

SECTION 109

WAGON LOADERS

(See Chutes)

These machines are generally of the bucket type in which an endless chain equipped with buckets rotates on a frame of varying length. It may be equipped with a gasoline engine or electric motor and is arranged in some cases to dig into the stock pile it is handling. It is mounted on wheels for easy transportation and where there is any great amount of loading to be done

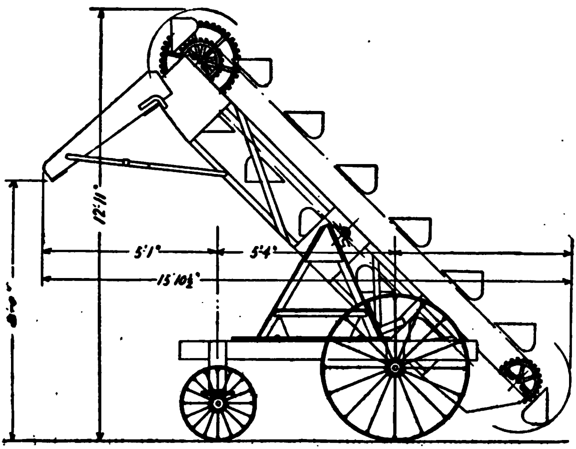


Fig. 342. "Digging" Wagon Loader

will effect a saving over hand labor not only in the actual handling of the material, but also in the time saved in loading the trucks, which will enable them to make more frequent trips.

A digging wagon loader for digging and loading crushed stone, sand, gravel, etc.; having a loading capacity of from 1 to 1¼ cu. yd. per min. costs as follows f. o. b. New York:

7½ hp. electric motor, weight 4,500 lb. $1,425
8 hp. gasoline engine, weight 5,500 lb. 1,500

A self-propelled digging wagon loader, same capacity as above:

7½ hp. electric motor, weight, 5,000 lb. $1,730
8 hp. gasoline engine, weight 6,400 lb. 1,750

A self-propelled, path digging wagon loader, same capacity as above, with 8 ft. 6 in. clearance under chute:

10 hp. electric motor, weight 5,900 lb. $2,300
10 hp. gasoline engine, weight 6,800 lb. 2,250

Clearances up to 13 ft. 6 in. may be had at extra cost.

A wagon loader of a small size having a clearance under the chute of 7 ft., a capacity of 25 tons per hr., weight with 3 hp. electric motor 1,600 lb., costs $750. With 3 hp. gasoline engine, weight 1,800 lb., costs $750. With 4 hp. engine and feeding conveyor, $900. Shaker screen, $75 extra. Revolving screen, $125 extra.

Fig. 343. Loading Plant.

A wagon and truck loader of the bucket type, suitable for use with coal, sand, gravel, etc., is rated at from ½ to ⅘ tons per min. It weighs about 2,800 lb. without the engine or motor. With a 4 hp. gasoline engine the cost is $955. With d. c. motor the cost is about $1010.

A portable loading plant (Fig. 343) of three units, i. e., a side dump body on flanged wheels, a cable with pulleys and a structural steel trestle of 50 ft. length, 20% grade incline, 8 ft. high, single track, 6 ton capacity, complete with braces, rails, pulleys, etc., costs $800. The side dump body on flanged wheels is extra and may be had in capacities of from 2 to 10 cubic yards at from $530 to $1,250. Center divisions are from $30 to $60 extra.

One end of the cable is attached to the loading body, the cable passes longitudinally over the trestle guided by pulleys and rollers

and thence to a "dead man" set several hundred feet to the rear. By suitable sheaves between the dead man and the trestle any desired reduction of power can be obtained. By means of this cable, the truck coming up to receive the load furnishes the power to pull the loaded car up the trestle in position to dump. By having the cable of proper length it can be arranged to have the truck directly beside the trestle by the time the car reaches the top, so that the load can be transferred immediately.

This portable loading plant is suited to temporary gravel pits,

Fig. 344. Truck and Wagon Loader.

storage piles of coal and building material, shallow excavations and other work where overhead storage and conveyor systems are impractical.

A truck and wagon loader, similar to the one shown in Fig. 344 does not attach to the side of the car to be unloaded. It is built of steel and is made in the following sizes:

WAGON LOADER

Capacity cu. yd.	Weight in lb.	Price Plain	Price Wheels
¾	375	$195	...
1	400	205	...
1¼	460	215	$235
1½	500	225	250
2	600	...	270

Extra for trimmer, $35. The above loaders may be had with either one or two hoppers. The prices are approximate for each.

Truck Loader

Capacity cu. yd.	Weight in lb.	Price
1½	900	$310
2	1025	340
2½	1125	360
3	1225	380
3½	1325	415
4	1425	435
5	1700	485

The above are equipped with a trimmer and are of heavier construction than the wagon loaders Center divisions cost $25 extra. The above prices are approximate for loaders having one or two hoppers. The loaders having three hoppers are made in three capacities as follows: 4 cu. yd. $775; 4½ cu. yd. $800; and 5 cu. yd. $835.

SECTION 110

WELDING

Thermit Process. Thermit is a mixture of finely divided aluminum and iron oxide. When ignited in one spot, the combustion so started continues throughout the entire mass without supply of heat or power from outside and produces superheated liquid steel and superheated liquid slag (aluminum oxide). The thermit reaction produces an exceedingly high temperature, the liquid mass attaining 5,400° Fahrenheit in less than 30 seconds. The liquid steel produced by the reaction represents one-half of the original thermit by weight and one-third by volume.

Welding by the thermit process is accomplished by pouring superheated thermit steel around the parts to be united. Thermit steel, being approximately twice as hot as ordinary molten steel, dissolves the metal with which it comes in contact and amalgamates with it to form a single homogeneous mass when cooled. The essential steps are to clean the sections and remove enough metal to allow for a free flow of thermit steel, surround them with a mold, preheat by means of a gasoline and compressed air torch and then pour the steel. Full directions are supplied by the company owning this process and are not given here on account of the limited space.

The following detailed outfit is suitable for repair work on a small railroad or the equipment of a contractor, where the sections of wrought iron or steel do not exceed 4 x 6 in. in size:

Item	Price
1 automatic crucible No. 6	$ 25 00
1 double burner thermit preheating torch complete	85 00
1 tapping spade	.50
300-lb. thermit mixed with 1% manganese and 1% nickel thermit and 15% punchings	120 00
10 lb. yellow wax @ $0.35	3.50
1 bbl special moulding material for facing	5.00
1 lb. ignition powder	.90
Total cost, f. o. b. Jersey City	$239.90

The preheater is a permanent appliance and will last indefinitely, while the crucible will last from 12 to 16 reactions, after

which it may be relined with magnesia tar in the field or at the factory for $18. Each crucible requires 135 lb. of tar at 7 ct. per lb., and one magnesia stone. No construction equipment is required except necessary material to make a mould box of sheet iron.

The prices of other sizes of appliances are as follows:

Item	Price	Weight (lb.)
Preheater torch, single burner	$60.00	175
Preheater torch, double burner	85.00	200
Automatic crucible, No. 1, for 6 lb. thermit	5.00	40
Automatic crucible, No. 2, for 8 lb. thermit	8.50	60
Automatic crucible, No. 3, for 15 lb. thermit	12.00	110
Automatic crucible, No. 4, for 25 lb. thermit	13.50	125
Automatic crucible, No. 5, for 35 lb. thermit	15.00	150
Automatic crucible, No. 6, for 70 lb. thermit	25.00	225
Automatic crucible, No. 7, for 140 lb. thermit	45.00	385
Automatic crucible, No. 8, for 210 lb. thermit	55.00	480
Automatic crucible, No. 9, for 280 lb. thermit	65.00	580
Automatic crucible, No. 10, for 400 lb. thermit	80.00	720
*Tripods, No. 1	2.50	11
*Tripods, Nos. 2–3	3.50	19
*Tripods, Nos. 4–5	4.50	24
*Tripods, Nos. 6–7	12.50	65
Flat bottom crucibles, No. 2, for 4 lb. thermit	2.60	18
Flat bottom crucibles, No. 3, for 8 lb. thermit	5.45	27
Flat bottom crucibles, No. 4, for 16 lb. thermit	8.90	65
Flat bottom crucibles, No. 5, for 40 lb. thermit	11.65	95
Tongs for flat bottom crucible, No. 2	3.75	6½
Tongs for flat bottom crucible, No. 3	5.75	17½
Tongs for flat bottom crucible, No. 4	6.50	25
Tongs for flat bottom crucible, No. 5	7.00	30½
Cost of relining flat bottom crucible, No. 2	2.00	
Cost of relining flat bottom crucible, No. 3	4.15	
Cost of relining flat bottom crucible, No. 4	6.15	
Cost of relining flat bottom crucible, No. 5	9.35	
Thermit (sold only in 50 lb. boxes). Railroad	20.00	
Ignition powder, ½-lb. cans	.45	
Yellow wax, per lb.	.35	
Special moulding material, per bbl.	5.00	340

* For welding connecting rods and driving wheel spokes, etc.

The proper quantity of thermit required for the weld may be calculated by multiplying by 32 the weight of the wax necessary to fill all parts of the fracture and reinforcement, or else by calculating the number of cu. in. in the fracture and reinforcement and allowing one pound of thermit mixed with the necessary additions, to the cubic inch. If more than 10 lb. of thermit are to be used it is necessary to mix steel punchings, not exceeding ½-in. in diameter, into the powder. For 10 lb. or more of thermit 10% of punchings should be added; for 50 lb. or more 15% of punchings should be mixed in.

The railroad thermit mixture with proper ingredients is used for welding steel sections. No other additions are necessary.

Portable Oxy-Acetylene Welding and Cutting Outfit consisting

of an acetylene generator, regulator valves and gauges, connecting hose, burner, tool kit, goggles and gloves, complete without oxygen tank, costs $240 f. o. b. distributing point. A three wheel steel truck for this outfit costs $35 extra. This generator uses carbide cakes (see Light) and has a capacity of 80 cu. ft. of gas from 8 cakes.

Another make is to be had in three outfits. The welding outfit consists of a torch, acetylene generator, regulating valves and

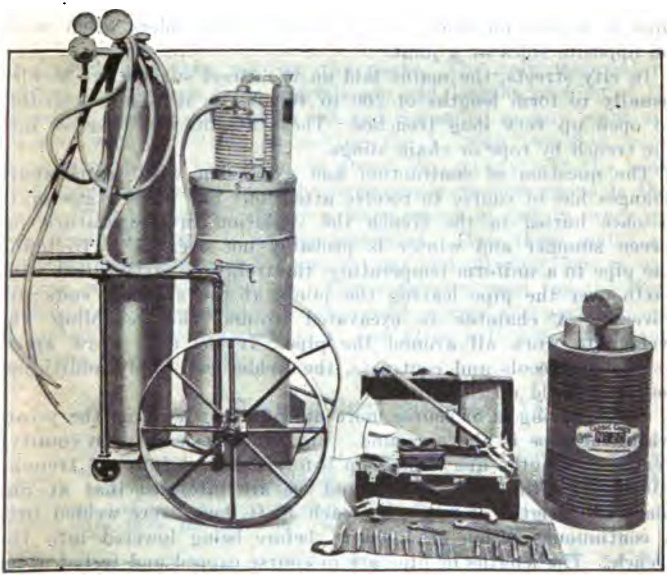


Fig. 345. Portable Welding Outfit.

gauges, hose, tools, goggles, complete on truck, and costs $127.50. The cutting outfit is similar to the above and costs $145. The combination outfit for both welding and cutting costs $195.

Welding the Joints of Steel Gas Mains. The following is from the Feb. 4, 1915, issue of *Engineering News*. An application of the oxy-acetylene system of welding together lengths of wrought iron or steel pipe to make a continuous line, thus eliminating either screwed or bolted joints, has been made in putting down some eleven miles of gas mains in Chicago. The diameters of the mains varied from 4 to 16 inches. Similar work has been done

at Philadelphia, and at the Panama-Pacific Exposition pipes welded in this way have been used for the entire gas-main system, comprising ten miles of pipes of 2-in. to 16-in. diameter. The smaller pipes also for gas distribution inside the Exposition buildings have been welded into continuous lengths.

The lengths of pipe are deposited along the street or on skids over the trench, and successive lengths are butted together. The pipe undergoing welding is turned gradually during the operation so that the welding is all done at the top. Where large pipe is welded on skids over a trench, two welders often work on opposite sides of a joint.

In city streets, the mains laid on the street surface are welded usually to form lengths of 200 to 400 ft., as it is not desirable to open up very long trenches. These lengths are lowered into the trench by rope or chain slings.

The question of contraction and expansion with temperature changes has of course to receive attention; but when a gas main is once buried in the trench the variation in temperature between summer and winter is probably not over 25°. To bring the pipe to a uniform temperature, the trench is partly filled with earth over the pipe leaving the joints at the abutting ends uncovered. A chamber is excavated around this, enabling the welder to work all around the pipe. If the ends draw apart as the pipe cools and contracts, the welder can apply additional metal to build up the joint.

Such welding is of course more difficult than welding the joints while the pipe is above ground. For this reason in open country very long lengths are welded up before lowering into the trench; 1,000-ft. lengths are common and we are informed that at one place 100 lengths of 8-in. pipe, each 40 ft. long, were welded into a continuous section of 4,000 ft. before being lowered into the trench. The lengths of pipe are of course capped and tested after welding the joints and before lowering into the trench.

The welded joint is claimed to have usually from 80 to 90% the strength of the solid pipe, but can be made even stronger than the pipe by building up additional metal. The life of the pipe should be greatly increased since the thickness of the pipe is not reduced by cutting the threads upon it. The lengths of pipe to be welded are made preferably with beveled ends, new metal being built up in the V-shaped opening at the joint, but square end pipe can be welded if necessary. The use of this process is leading to the adoption of 40 ft. lengths in preference to the usual 20 ft. length.

Under ordinary conditions a skillful operator can weld in an hour about one joint on 12-in. pipe and from three to five joints

on 4-in. pipe. The cost is said to be from 25 to 40% less than the cost of a recessed screw joint, including the cost of the coupling and its application.

With the welded pipe, the branches, laterals, drips and various other fittings are made integral parts of the continuous main, while with screw-joint pipe they are separate and special parts whose numerous joints are often a source of trouble. Laterals are inserted at any point by cutting a hole in the main (with the cutting blowpipe) and welding in the end of the lateral. A 6-in. angle, an 8-in. Y and a 6- and 4-in. reducer were made by cutting the main and the smaller pipe to the desired shape with the torch and then welding the parts. The only material required to make up these specials are odd lengths of pipe of the required sizes, which can be cut and connected at any point and in any way. The cost of making the Y, with two 8-in. pipes connecting to an 8-in. main, is about 76c., as given in the table.

A great advantage of such continuously welded mains is that leaks from the joints, always a large source of loss in every gas distribution system, is wholly prevented. Thus these mains are especially advantageous for natural gas and oil pipe lines as well as for city gas distribution. The apparatus used for the work consists of two cylinders of compressed oxygen and acetylene gas mounted on a two-wheeled truck, and fitted with hose, regulators and the welding torch.

COST OF WELDING PIPE JOINTS AND YS

	6-in. pipe		16-in. pipe		8 x 6-in. Y Cutting		8 x 6-in. Y Welding	
Labor, 30 ct. per hr...........min.	20	$0.10	90	$0.45	3	$0.015	22	$0.11
Oxygen, 2 ct. per cu. ft.......ft.	10	.20	40	.80	3	.06	12	.24
Acetylene, 2 ct. per cu. ft.....ft.	9	.18	36	.72	1	.02	10	.20
Filling wire, 12 ct. per lb......lb.	¾	.09	2	.24	..	...	1	.12
Total		$0.57		$2.21		$0.095		$0.67

SECTION 111

WHEELBARROWS

Analysis of the Wheel-Barrow. The wheel-barrow, as a means for transportation, is subject to such peculiar laws and it is so often used under false assumptions that it deserves some careful analysis. The wheel-barrow itself is a very remarkable vehicle. Its front end is subject to the rules that govern the transportation of wheeled vehicles proper and its rear end is dead weight carried upon the hands of its operator, while it has a third peculiarity in that the man who carries the load must at the same time furnish the tractive power for overcoming the wheel resistance. It is a highly specialized form of apparatus suitable for a highly specialized kind of work and nothing else.

Wheel Traction. The causes of resistance to the motion of a wheeled vehicle are as follows:

1. Friction at the axle.
2. Rolling friction under the wheel.
3. The effect of grade.

The first of these is inconsiderable and pretty nearly constant for ordinary vehicles, being from 3½ to 4½ pounds per short ton. The second, the rolling friction underneath the wheel, depends upon the diameter of the wheel itself, width of tire, the road surface, the number of wheels in the vehicle, and, also, upon the kind of vehicle, whether it is supported by springs or otherwise, and the manner in which the load of the vehicle is distributed among the wheels.

The force which overcomes the wheel resistance must act in a direction parallel with the traction surface; or if it is not parallel with the traction surface, only the component of the force which is parallel with the surface is effective.

Wheel-Barrow. In the wheel-barrow all of the forces which act underneath the wheel can be theoretically considered as due to an equivalent grade with all friction omitted. In the diagram Fig. 346, W is represented as the total weight of the wheel-barrow and its load, and in the sketch A, this load is considered as acting at a point whose distance measured horizontally is d from the center of the wheel and d_1 from the handle. The wheel

rolls upon the theoretical grade line and presses upon it with a force which is equal and opposite to the reaction R_1, which acts normally to this grade line. The intensity of R_1 depends upon the weight W and its position. The nearer W is to the wheel the greater its reaction but the direction of the reaction always remains at right angles to the theoretical grade. The only other force supporting the wheel-barrow is that applied at the handles

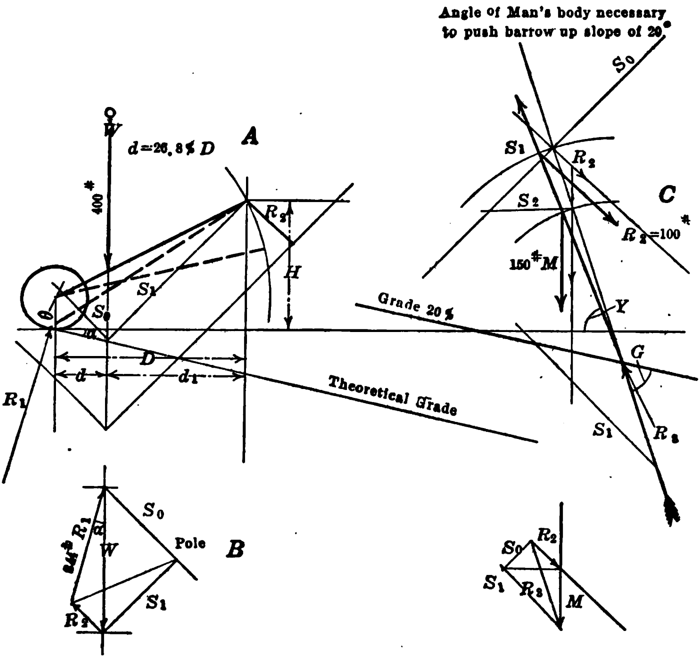


Fig. 346

and is indicated by R_2. These forces have been worked out to scale in the Equilibrium Diagram B.

The applied force R_1 is derived from the pull on the arms of the operator transmitted through his body from the shoulder point, and transmitted thence through his body to the point at which his feet meet the ground g. In order that the man's body shall not be overturned, he must lean forward in such a position that the moment of the force R_2 around the point g will be

balanced by the moment of the man's weight acting at the center of gravity of his body in the opposite direction. By trial this proposition will establish the angle at which the man's body should stand, which in the diagram is the angle Y with the horizontal. An inspection of this diagram will disclose the following facts:

1. When the load W is well forward near the wheel, as a result of this condition the force R_2 necessarily takes a direction oblique to the vertical, and, therefore, when this force must be resisted by the arms of the operator, his arms extending out backward must approach the more nearly to a horizontal line the farther forward W is placed. Likewise, in order to maintain his body in equilibrium he must lean forward proportionately with the increase in the obliqueness of this force.

2. The farther forward he leans the more cramped and painful does his position become and the less secure his foot-hold, also, the greater the general strain upon his body.

3. Conversely, if the load W be moved toward the handles, the direction of R_2 becomes less oblique to the vertical and a man can stand more nearly upright and yet preserve his equilibrium. At the same time it is clear that with the decrease in the obliquity of R_2 with the vertical, the load R_1, which is the reaction under the wheel, decreases and the total amount of R_2 increases, placing a larger muscular strain upon the arms of the operator.

4. As a result of these facts we have the following propositions, namely:

(1) That for a level grade on a smooth surface, requiring a small relative horizontal component of R_2 in order to overcome the tractional resistance, a very large load can be placed over the wheel.

(2) As soon, however, as it becomes necessary to ascend an appreciable grade, or push the wheel-barrow through soft earth or material involving a considerable resistance to traction, it becomes necessary to have a substantial vertical component to R_2 and involves shifting the load towards the handles.

(3) The total load upon the handles is limited to about 100 pounds for ordinary work where the wheel-barrow is in use most of the time; and this fact being established, it is advisable to design for particular conditions a wheel-barrow which will meet them with the least waste of energy.

These principles have been made use of to some extent in the two-wheeled concrete bucket which, loaded with 600 pounds of

concrete, is easily pushed by one man upon a level or down a slight grade, if the traction surface is in good condition. Earth has been moved with great economy down slight grades by the construction of some homemade push carts which would carry a very large load and could be easily pushed by one man.

I have at hand a list of some twenty-six different styles of wheel-barrows in ordinary use, in which the maximum ratio of D is nearly 40 %, a minimum of about 17%, and the average over 28%. The weight of the wheel-barrows, themselves, varies from 42–110 pounds with an average of 70 pounds. The value of D varies from a minimum of 45″ to a maximum of 55″ with an average of 48″. The wheel diameters average 15 or 16″.

Chinese Wheel-Barrow: The above discussion permits us to analyse and appreciate one of the most remarkable forms of apparatus in the world, namely, the Chinese wheel-barrow. Mr. Charles Mayne has described the kind in use in and near Shanghai. The salient features are as follows:

Weight of barrow, light, 120 pounds.

Length, including shafts, 6 ft. 6″.

Extreme breadth, including platform and spread of handles, 3 ft. 2″.

Diameter of wheel, 3 ft.

Width of tire, 1¼″.

Height from ground level, including wheel guard, 3 ft. 5″.

The frame is made of oak, the shafts at the rear end having a spread of 3 ft. 1″, from a point about 4 ft. 10″ from the center of the wheel. The apparatus is steadied by a strap which goes over the shoulders of the barrow man. Mr. Mayne states that frequently fifty wheel-barrows may be seen travelling in a line in Shanghai, each carrying two barrels of English Portland cement, and propelled by one man. Since the gross weight of a barrel of cement is about 400 pounds, the gross load is about 920 pounds which may be taken as pretty nearly the practicable maximum. Mr. Mayne observes that this traffic is very damaging to the macadam roads. Frequently, a wheel-barrow will have a load on one side only, in which case it is necessary to tilt the wheel over in order to balance the load, and this tilting results in the edge of the tire cutting into the macadam. Granite broken into ¾″ size seems to be the only material that will stand up under this treatment. The resistance per ton on a level macadam road is about 40 pounds. It will therefore require a push of about 20 pounds to propel one of these vehicles, loaded with two barrels of Portland cement, which is not above the capacity of an ordinary coolie. It will be noted that here the center of gravity of the load is directly in the vertical plane

which includes the axle, and that the height of the center of gravity of the whole apparatus is probably 15 or 16″ above the axle. When the wheel-barrow strikes an ascending grade the most remarkable function of this machine comes into play: the ground on which the wheel rests being slightly higher than that on which the barrow man walks, the center of gravity of the load is shifted to a position abaft the axle, which induces a vertical load upon the hands of the barrow man, enabling him to preserve his own balance and apply more and more strength to the pushing of the load as the grade increases, which we see from Fig. 350 is accomplished in the ordinary American wheel-

Fig. 347. Average Barrow Load — 0.078 cu. yd. Loose.

barrow by always having the load abaft the wheel. The Chinaman has then automatically, as it were, a mechanism that adjusts itself to the exigencies of the traffic, and enables him to operate with at least three times the efficiency for transportation purposes of the ordinary wheel-barrow in use in this country and Europe. It will be noted that the Chinese wheelbarrow has no bowl for convenience in loading granular materials and it is not adapted for dumping.

A further comment upon the above facts is that it is highly advantageous in all wheel-barrow work to lay a plank-way, which will permit the wheel-barrow to operate with a minimum of resistance. The above discussion incidentally explains why at least one observer is of the opinion that there is no great dif-

ference in the economy of wheel-barrow operations between level work and grades of 5%. The difference is there but it is hard to see because of the exceedingly inefficient design of the average wheel-barrow.

Wheel-Barrow Capacity. Mr. James N. Harlow, found in 1879 on work in the Ohio River that 7,959 wheel-barrow loads of sandy loam averaged 0.057 cubic yards per load, weighing

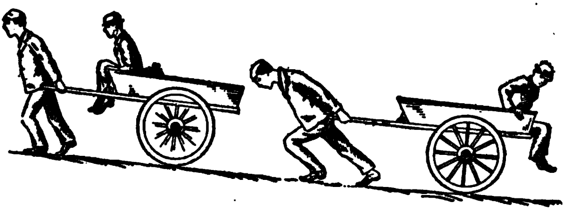


Fig. 348. If you are going up hill with a truck, which of these two ways is easier, and why?

183 pounds per cubic foot of 1.54 cubic feet per wheel-barrow.

The same authority at Davis Island found the 3,484 wheel-barrow loads of gravel averaged 0.546 or 1.47 cubic feet per barrow. Taking the weight of gravel as 125 pounds per cubic foot it would be 184 pounds net per wheel-barrow.

Mr. Allen Hazen states that 23,180 wheel-barrow loads of

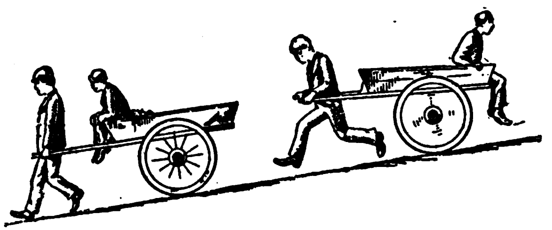


Fig. 349. If you travel down hill with a truck, which of the above ways is easier, and why?

sand averaged .3566 yards per barrow. These figures were obtained on the scraping of filters. The wheel-barrows, loaded as in the cut (Fig. 347), average .0779 cubic yards per barrow loose, or assuming 45% voids 198 pounds per barrow load net. The average barrow load figures out .0427 loads per yard solid. Explained in fractions, wheel-barrow loads as loaded in the pho-

tograph will average about 1/23 of a yard solid or 1/13 of a yard loose.

Hand Carts. The hand cart is used in Europe to a large extent and with appreciation of the laws noted in this analysis, which laws are also illustrated by the two sketches (Figs. 348 and 349) from the *Strand Magazine* for October, 1908. When pushing steadily on a cart a man can turn out about one-half million foot pounds of work in ten hours.

The following notes are of advantage in figuring on wheelbarrow work in general. According to Haswell, a man can carry 111 pounds 11 miles per day, and going short distances and returning unloaded he can transport in a wheel-barrow 150 pounds 11 miles per day. We have seen that this latter performance depends entirely upon the kind of wheel-barrow and the kind of traction surface. Haswell also states that a man

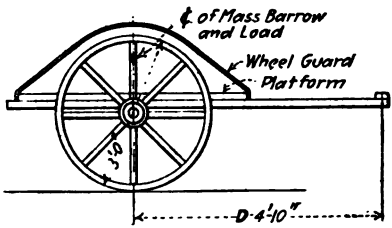


Fig. 350

can push on a horizontal plane 20 pounds with a velocity of 120 feet per minute for ten hours per day. This result seems to accord with those of Morin.

The Cost of Wheel-Barrow Work. The value of D, which we have considered as the "lead" or "haul," is the distance in feet that the material has to be carried, not including the extra distance traversed in the operation of turning around. In scraper and general embankment work it is feasible to ascertain this value quite accurately by means of a profile, and is in effect the distance between the centers of gravity of the cut and fill.

For the wheel-barrow under ordinary conditions of work in this country the lost time per round trip, or "l," will average very nearly three-quarters of a minute on an ordinarily well managed job. The loaded speed will differ from the empty in different ways, depending upon the conditions. When delivering concrete up a moderate grade, say 5-10%, the man with the loaded wheel-barrow will almost invariably walk some 10% faster

than the man with the empty wheel-barrow, the man with the heavy loaded wheel-barrow being anxious to get ahead and dump his load, getting his rest on a slow return trip. The men, wheeling materials to a mixer, as a general thing have to go up a slight grade and are subject to the same rule, whereas the wheel-barrow, when wheeling heavy loads down hill, is inclined to pull the man with it, and the loaded barrow again goes faster than the empty one. On a level in earth work where the

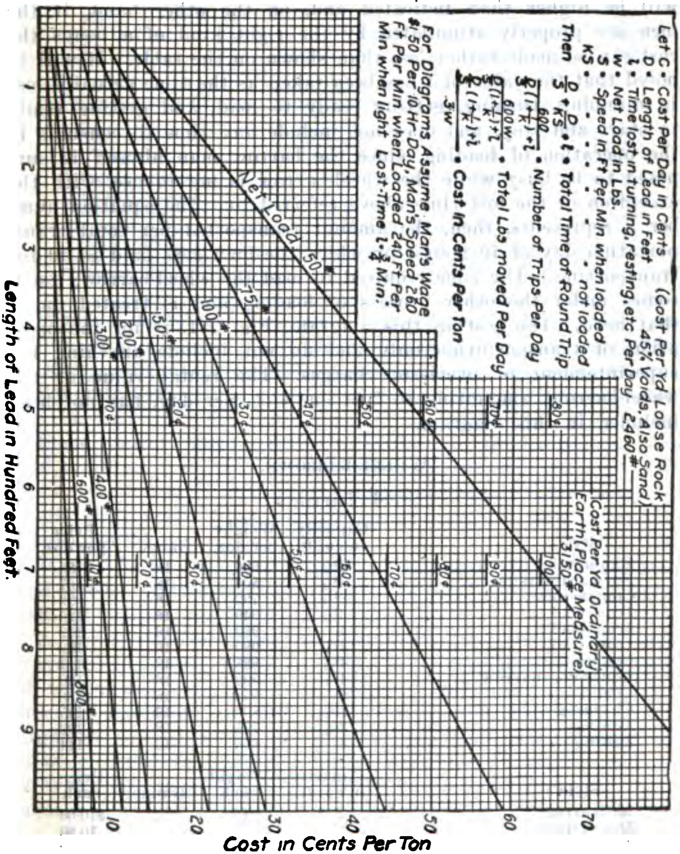


Fig. 351. Transportation by Wheel-barrow.

haul is rather long, the loaded wheel-barrow will move rather more slowly than the empty one. For convenient use in the field the diagram in Fig. 351 has been plotted and shows the actual total cost per ton and per cubic yard for different materials for any length of haul up to 1,000 feet which can be read off directly. This diagram is made for average contract work when the day's wages are $1.50 per day of 10 hours, and when the conditions are as outlined above. If the men are loafing the cost will be higher than indicated and, on the other hand, if the men are properly stimulated by the right kind of a bonus the cost can be made rather less than shown on the table. It will be noted that the value of l has been taken as the time actually lost in dumping, turning, getting ready to load, and getting ready to start and stop, and does not include any time to consume in the operation of loading, since the barrow man himself is supposed to be busy while the wheel-barrow is not in use, with the exception of the lost time above referred to. The equation number 5 represents, then, the amount transported per total transportation day of 10 hours for which the man gets paid $1.50 for transporting. The time required to load the wheel-barrow, itself, comes under the other process of loading and is treated under that head. The cost in this diagram, Fig. 351, is for the operation of transportation only and do not include anything for superintendent or overhead charges. The rental value of the wheel-barrow, amounting to 2 ct. or 3 ct. per day, has not been included in this diagram.

WHEEL-BARROWS.

Steel barrows.

Style	Capacity in cu. ft.	Weight per doz.	Gauge	Price per doz.
Panhandle	3½	696	18	$ 88
Forward dump	3½	804	16	107
Contractors	3½	792	16	96
Iron clad	3½	940	16	120
Iron clad	4	980	16	132
Iron clad	4¼	980	16	132
Concrete	4½	888	16	113
Concrete, narrow	4¾	900	16	120
Coal	5	954	16	138
Charging	3½	800	16	145
Mining	3¼	738	18	102
Mining	4	858	16	114

Style	Capacity in cu. ft.	Weight each	Gauge	Price each
Measuring	2	68	..	$10.00
Measuring	2½	73	..	10.80
Measuring	3	78	..	11.60
Coal	6	90	14	13.00
Coke	9	105	14	18.00
Concrete conveyor	4½	87	16	15.00

Wooden barrows.

Brick and tile, weight per doz, 820 lb., load capacity 700 lb., per doz. $85. Cement bag barrow, weight each 75 lb., load capacity 700 lb., price each $12.

Concrete carts.

Concrete capacity in cu. ft.	Weight each	Wheels in inches	Gauge	Price each
4½	170	30	14	$30
6	188	30	14	32
6	196	36	14	34
6	246	42	12	40

Another make of steel wheel-barrows is as follows:

Kind	Capacity cu. ft.	Weight each	Price each
General purpose	3	57	$ 6.50
General purpose	4	59	7.00
General purpose	6	64	7.75
Concrete	2 to 4	74	8.50
Tubular steel	3	71	9.00
Tubular steel	4	78	10.50
Tubular steel	6	103	13.00

Wooden Barrows. A wooden brick barrow having a platform 28 by 24 in., and an 18 ft. dash weighs 67 lb., and costs $7.00. A straight handle stone barrow weighs 73 lb., and costs $7.50.

Concrete Cart with a capacity of 6 cu. ft., weighs approximately 204 lb., and costs $34.

Some wooden wheel-barrows which cost originally $21 per doz. had a life of 6 months in rock work and about 1 year in earth work; they would last still longer in concrete, this being for single shift work. The average cost of repairs was 30 ct. per month per barrow.

It was found that wheel-barrows with steel trays, iron wheels and wooden frames had about the same total life but the average cost for repairs was 20 ct. per month.

A dozen wooden frame barrows with steel wheels and steel trays costing $30 per doz. were useless in 6 months in work 80% of which was rock and 20% earth. Total repairs for these 6 months amounted to $10, or 14 ct. per barrow per month. Eighteen wheel-barrows, costing $60 per doz. were bought, one of which survived 6 months of the same kind of work. The cost of renewing trays for these was $1 per wheel-barrow for the 6 months and general repairs amounted to $30, or 28 ct. per barrow per month. Of another dozen costing $27 with wooden trays and steel wheels 10 survived 6 months' work at a total cost for repairs of $28, or 39 ct. per barrow per month.

SECTION 112

WINCHES

Double drum, double purchase winch, capacity with 2 men, 2 lines 10,000 lb., with 2 men, 4 lines 20,000 lb., diameter of drum 9 in., costs from $114 to $124 for lengths from 14 to 20 in.

Single drum, double purchase winch same as above costs from $103 to $112.

Double drum geared winch capacity 2 men, 2 lines 3,000 lb., 2 men, 4 lines 6,000 lb., diameter of drum 5 in., lengths from 14 to 18 in., $64 to $66. 7 in. diameter, $68.20 to $70.40.

Single drum geared winch same capacity and sizes as above costs from $33 to $38 50.

Double drum geared winch, capacity 2,000 to 3,000 lb., drum 4 by 8, $42.

Single drum geared winch, as above, $17.

Small winch, not geared, 800 to 1,600 lb. capacity, $7.70.

Safety worm gear winch, 750 to 1,500 lb. capacity, $14.50.

APPENDIX

CLASSIFIED LIST OF CONSTRUCTION EQUIPMENT MANUFACTURERS AND DEALERS

APPENDIX

AIR COMPRESSORS

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Blake-Knowles Works, New York, N. Y.
Chicago Pneumatic Tool Co., Chicago, Ill.
Fairbanks, Morse & Co., Chicago, Ill.
Ingersoll-Rand Co., New York, N Y.
Sullivan Machinery Co., Chicago, Ill.
Westinghouse Air Brake Co., Pittsburg, Pa.
Worthington Pump & Machinery Corp., New York, N. Y.

AIR COMPRESSORS — PORTABLE

Abenague Mach. Works, Westminster Station, Vt.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Chicago Pneumatic Tool Co., Chicago, Ill.
Fairbanks, Morse & Co., Chicago, Ill.
Ingersoll-Rand Co., New York, N. Y.
Sullivan Machinery Co., Chicago, Ill.

ASBESTOS

Acme Asbestos Covering & Supply Co., Chicago, Ill.
Dominion Asbestos & Rubber Co., New York, N. Y.
Johns-Manville Co., H. W., New York, N. Y.
Wing & Son, R. B., Albany, N. Y.

ASPHALT PLANTS

Austin Co., F. C., Chicago, Ill.
Barber Asphalt Paving Co., The, Philadelphia, Pa.
Cummer & Son Co., The F. D., Cleveland, O.

AUTOMOBILES — MOTOR TRUCKS

Federal Motor Truck Co., Detroit, Mich.
Garford Motor Truck Co, The., Lima, Ohio.
International Harvester Co., Chicago, Ill.
Kelly-Springfield Motor Truck Co., Springfield, O.
Packard Motor Car Co., Detroit, Mich.
Pierce-Arrow Motor Car Co., Buffalo, N. Y.
Reo Motor Car Co., Lansing, Mich.

Republic Motor Truck Co., Alma, Mich.
Stewart Motor Corp., Buffalo, N. Y.
Tiffin Wagon Co., Tiffin, Ohio.
White Co., The, Cleveland, Ohio.

BACKFILLING MACHINES

Austin Co., F. C., Chicago, Ill.
Parsons Co., The, Newton, Ia.
Pawling & Harnischfeger Co., Milwaukee, Wis.
Waterloo Cement Machinery Corp., Waterloo, Ia.

BAR CUTTERS

Cleveland Punch & Shear Works Co., The, Cleveland, O.
Koehring Machine Co., Milwaukee, Wis.
Mesta Machine Co, Pittsburg, Pa.
Niagara Machine & Tool Works, Buffalo, N. Y.
Ryerson & Son, Jos. T., Chicago, Ill.

BARGES AND SCOWS

American Bridge Co., New York, N. Y.
California Redwood Assn., San Francisco, Cal.
Fabricated Steel Products Corp., New York, N. Y.
Graver Tank Works, Wm., East Chicago, Ind.
Pittsburg-Des Moines Steel Co., Pittsburg, Pa.

BELTING

Allen Mfg. Co., W. D., Chicago, Ill.
Bicford & Francis Belting Co., Buffalo, N. Y.
Fairbanks Co., The, New York, N. Y.
Hettrick Mfg. Co., The, Toledo, O.
Manheim Mfg. & Belting Co., Chicago, Ill.
Salisbury & Co., Inc., W H., Chicago, Ill.
Union Asbestos & Rubber Co., Chicago, Ill.

BENDING MACHINES

Electric Welding Co., Pittsburg, Pa.
Galland-Henning Mfg. Co., Milwaukee, Wis.
Hinman & Co., Sandwich, Ill.
Koehring Machine Co., Milwaukee, Wis.
Ryerson & Son, Jos. T., Chicago, Ill.
Watson-Stillman Co., The, New York, N. Y.

BINS

Good Roads Machinery Co., Kennett Square, Pa.
Weller Mfg. Co., New York, N. Y.

BLASTING MACHINES

Atlas Powder Co., Wilmington, Del.
du Pont deNemours Co., E. I., Wilmington, Del.
Rendrock Powder Co., New York, N. Y.
Western Electric Co., New York, N. Y.

BLOCKS — TACKLE

American Hoist & Derrick Co., St. Paul, Minn.
Boston & Lockport Block Co., Boston, Mass.
Burr Mfg. Co., Cleveland, O.
Byers Machine Co., Jno. F., Ravenna, O.
Carpenter & Co., Geo. B., Chicago, Ill.
Clyde Iron Works, Duluth, Minn.
Edwards & Co., H. D., Detroit, Mich.
Hartz Co., H. V., Cleveland, O.
Leschen & Sons Rope Co., A., St. Louis, Mo.
Roebling Sons Co., Jno. A., New York, N. Y.

BLUE PRINT MACHINES

Dietzgen Co., Eugene, Chicago, Ill.
Keuffel & Esser, New York, N. Y.
Wickes Bros., Saginaw, Mich.

BOILERS

Ames Iron Works, Oswego, N. Y.
Abendroth & Root Mfg. Co., Newburg, N. Y.
American Radiator Co., Chicago, Ill.
Babcock & Wilcox, New York, N. Y.
Brennan & Co., John, Detroit, Mich.
Brownell Co., Dayton, O.
Byers Co., Jno. F., Ravenna, O.
Casey-Hedges Co., Chattanooga, Tenn.
Connelly Boiler Co., D., Cleveland, O.
Frick Co., Waynesboro, Pa.
Johnston Bros., Ferrysburg, Mich.
Kewanee Boiler Co., Kewanee, Ill.
Lake Erie Boiler Works, Buffalo, N. Y.
Union Iron Works, Erie, Pa.

BUCKETS — CONCRETE

Haiss Mfg. Co., New York, N. Y.
Hayward Co., The, New York, N. Y.
Industrial Works, Bay City, Mich.
Insley Mfg. Co., Indianapolis, Ind.
Koppel Industrial Car & Equipment Co., Koppel, Pa.
Lakewood Engineering Co., The, Cleveland, O.

Marsh & Co., Geo. C., Chicago, Ill.
Mead Morrison Mfg. Co., East Boston, Mass.
Steubner, Geo. L., Long Island, N. Y.

BUCKETS — GRAB

Brosius, Edgar E., Pittsburg, Pa.
Brown Hoisting Machinery Co., The, Cleveland, O.
Haiss Mfg. Co., New York, N. Y.
Hayward Co., The New York, N. Y.
Industrial Iron Works, Bay City, Mich.
Lakewood Engineering Co., Cleveland, O.
Link-Belt Co., Chicago, Ill.
Orton & Steinbrenner Co., Chicago, Ill.
Pawling & Harnischfeger Co., Milwaukee, Wis.
Williams Co., G. H., Erie, Pa.

BUCKETS — SCRAPER

American Hoist & Derrick Co., St. Paul, Minn.
Blaw-Knox Co., Pittsburg, Pa.
Brown Hoisting Machinery Co., Cleveland, O.
Bucyrus Co., So. Milwaukee, Wis.
Haiss Mfg. Co., Geo., New York, N. Y.
Hayward Co., The, New York, N. Y.
Industrial Works, Bay City, Mich.
Link-Belt Co., Chicago, Ill
Marsh & Co., Geo. C., Chicago, Ill.
Orton & Steinbrenner Co., Chicago, Ill.
Owen Bucket Co., Cleveland, Ohio.
Sauerman Bros., Chicago, Ill
Williams Co., G. H., Erie, Pa.

BUILDINGS — PORTABLE

Baker & Co., E. J., Chicago, Ill.
Butler Mfg. Co., Kansas City, Mo.
Edwards Mfg. Co., The, Cincinnati, O.
International Mill & Timber Co., Bay City, Mich.
Lucey Mfg. Corp., New York, N. Y.
Milwaukee Corrugating Co., Milwaukee, Wis.
Pruden Co., The C. D., Baltimore, Md.

CABLEWAYS

American Steel & Wire Co., Chicago, Ill.
Clyde Iron Works, Duluth, Minn.
Flory Mfg. Co., S., Bangor, Pa.
Lidgerwood Mfg. Co., New York, N. Y.
Roebling Sons Co., Jno. A., Trenton, N. J.
Sauerman Bros., Chicago, Ill.

CARS — CONTRACTORS'

Cambria Steel Co., Philadelphia, Pa.
Clark Car Co., Pittsburg, Pa.
Koppel Industrial Car & Equipment Co., Koppel, Pa.
Lakewood Engineering Co., The, Cleveland, O.
Western Wheeled Scraper Co., Aurora, Ill.
Youngstown Steel Car Co., The, Youngstown, O.

CARS — DUMP

American Car & Foundry Co., St. Louis, Mo.
Cambria Steel Co., Philadelphia, Pa.
Clark Car Co., Pittsburg, Pa.
Koppel Industrial Car & Equipment Co., Koppel, Pa.
Lakewood Engineering Co., The, Cleveland, Ohio.
Pidgeon-Thomas Iron Co, Memphis, Tenn.
Pressed Steel Car Co., Pittsburg, Pa.
Standard Steel Car Co., Pittsburg, Pa.
Western Steel Car & Foundry Co., Pittsburg, Pa.
Western Wheeled Scraper Co., Aurora, Ill.
Youngstown Steel Car Co., Youngstown, Ohio.

CARS — SPREADER

Buffalo Pitts Co., Buffalo, N. Y.
Jordan Co., O. F., East Chicago, Ind.
Lakewood Engineering Co., The, Cleveland, O.
Western Wheeled Scraper Co., Aurora, Ill.

CARTS — CONCRETE

Lakewood Engineering Co., The, Cleveland, Ohio.
Ransome-Leach Co., Dunellen, N J.
Sterling Wheelbarrow Co., Milwaukee, Wis.
Toledo Wheelbarrow Co., Toledo, O.

CARTS — DUMPING

Columbia Wagon Co., Columbia, Pa.
Kilbourne & Jacobs Mfg. Co, Columbus, O.
Lakewood Engineering Co., The, Cleveland, O.
Sterling Wheelbarrow Co., Milwaukee, Wis.
Tiffin Wagon Co., Tiffin O.
Western Wheeled Scraper Co., Aurora, Ill.

CEMENT GUNS

Cement-Gun Co., Inc., Allentown, Pa.

CEMENT TESTING APPARATUS

Fairbanks, Morse & Co., Chicago, Ill.

CHAIN BLOCKS

Abell-Howe Co., The, Chicago, Ill.
Chisholm, John E., Chicago, Ill.
Detroit Hoist & Machine Co., Detroit, Mich.
Reading Chain & Block Corp., Reading, Pa.
Ryerson & Son, Jos. T., Chicago, Ill.
Yale & Towne Mfg. Co., The, New York.

CHAINS

American Chain Co., Inc., Bridgeport, Conn.
Carr Co., The J. B., Troy, N Y.
Jeffrey Mfg Co., Columbus, Ohio.
Reading Chain & Block Corp., Reading, Pa.
United States Chain & Forging Co., Pittsburg, Pa.
Woodhouse Chain Works, Trenton, N. J.

CHUTES — BROKEN STONE, GRAVEL & SAND

American Abrasive Metals Co., New York, N. Y.
Fairbanks, Morse & Co, Chicago, Ill.
Link-Belt Co., Chicago, Ill.
Sackett Screen & Chute Co., H. B., Chicago, Ill.
Webster Mfg. Co, Tiffin, O.
Western Pipe & Steel Co., San Francisco, Cal.

CHUTES — CAR UNLOADING

Bonney Supply Co., Inc., The, Rochester, N. Y.
Heltzel Steel Form & Iron Co., Warren, Ohio.

CONCRETE PLACING EQUIPMENT

Insley Mfg. Co., New York, N. Y.
Lakewood Engineering Co., The, Cleveland, O.
Sackett Screen & Chute Co., H. B., Chicago, Ill.
Smith Co., The T. L., Milwaukee, Wis.

CONCRETE SIDEWALK AND CURB FORMS

Blaw-Knox Co., Pittsburg, Pa.

CONCRETE SIDEWALK TOOLS

Abram Cement Tool Co., Detroit, Mich.
Carpenter & Co, Geo. B., Chicago, Ill.

CONVEYORS — BELT

Alvey Mfg. Co., St. Louis, Mo.
Barber-Greene Co., Aurora, Ill.
Fairbanks Co., The, New York, N. Y.

Link Belt Co., Chicago, Ill.
Robins Conveying Belt Co., New York, N. Y.
Stephens-Adamson Co., Aurora, Ill.

CONVEYORS — PORTABLE

Barber-Greene Co., Aurora, Ill.
Portable Machinery Co., Passaic, N. J.

CRUSHERS

Acme Road Machinery Co., Frankfort, N. Y.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Austin Mfg. Co., Chicago, Ill.
Buchanan Co., Inc., New York, N. Y.
Case Threshing Machine Co., J. I., Racine, Wis.
Chalmers & Williams, Chicago, Ill.
Good Roads Machinery Co., Kennett Square, Pa.
Jeffry Mfg Co., Columbus, O.
Marsh & Co., Geo. C., Chicago, Ill.
Smith Engineering Works, Milwaukee, Wis.
Traylor Engineering & Mfg. Co., Allentown, Pa.
Western Wheeled Scraper Co., Aurora, Ill.

DERRICKS

American Hoist & Derrick Co., St. Paul, Minn
Byers Machine Co., Jno. F., Ravenna, O.
Clyde Iron Works, Duluth, Minn.
Flory Mfg. Co., S., Bangor, Pa.
Hoisting Machinery Co., New York, N. Y.
Pollard, J. G., Brooklyn, N. Y.
Parker, S. E., Chicago, Ill.
Sasgen Derrick Co, The, Chicago, Ill.
Terry Mfg. Co., The E. F., New York, N. Y.

DITCHERS

American Hoist & Derrick Co., St. Paul, Minn.
Austin Co., Inc., F. C., Chicago, Ill.
Bay City Dredge Works, Bay City, Mich.
Buckeye Traction Ditcher Co., The, Findlay, O.
Bucyrus Co., The, So Milwaukee, Wis.
Clyde Iron Works, Duluth, Minn.
Fairbanks Steam Shovel Co., Marion, O.
Good Roads Machinery Co., Kennett Square, Pa.
Hayward Co., The, New York, N. Y.
Jordan Co., O. F., East Chicago, Ind.
Osgood Co., The, Marion, O.
Western Wheeled Scraper Co., Aurora, Ill.

DIVING APPARATUS

Hale Rubber Co., Atlantic, Mass.
Morse & Son, Inc., Andrew J., Boston, Mass.
Schrader & Son, A., New York, N. Y.

DRAG SCRAPER EXCAVATORS

Austin Co., Inc., The F. C., Chicago, Ill.
Browning Co., The, Cleveland, Ohio.
Bucyrus Co., The, So. Milwaukee, Wis.
Clyde Iron Works, Duluth, Minn.
Fairbanks Steam Shovel Co., Marion, O.
Hayward Co., The, New York, N. Y.
Kilbourne & Jacobs Mfg. Co., The, Columbus, O.
Link-Belt Co., Chicago, Ill.
Marsh & Co., Geo. C., Chicago, Ill.
Orton & Steinbrenner, Chicago, Ill.
Osgood Co., The, Marion, O.
Pawling & Harnischfeger, Milwaukee, Wis.
Sauerman Bros., Chicago, Ill.
Williams Co., G. H., Erie, Pa.

DREDGES

Bay City Dredge Works, Bay City, Mich.
Bucyrus Co., The, Milwaukee, Wis.
Hayward Co., The, New York, N. Y.
Pittsburg-Des Moines Steel Co., Pittsburg, Pa.
Marion Steam Shovel Co., Marion, O.
Morris Machine Works, Baldwinsville, N. Y.
Portland Co., Portland, Me.
Stockton Iron Works, Stockton, Cal.
Toledo Foundry & Machine Co., Toledo, O.
Yuba Mfg. Co., Marysville, Cal.

DRILLS — BLAST HOLE AND QUARRY

American Well Works, Aurora, Ill.
Armstrong Mfg. Co., Waterloo, Ia.
Ingersoll-Rand Co., New York, N. Y.
Keystone Driller Co., Beaver Falls, Pa.
Sanderson-Cyclone Drill Co., Orrville, O.
Star Drilling Machine Co., The, Akron, O.
Sullivan Machinery Co., Chicago, Ill.

DRILLS — CORE

American Well Works, Aurora, Ill.
Dobbins Core Drill Co., New York, N. Y.
Ingersoll-Rand Co., New York, N. Y.

Jeffry Mfg. Co., Columbus, O.
Keystone Driller Co., Beaver Falls, Pa.
Standard Diamond Drill Co., Chicago, Ill.
Star Drilling Machine Co., The, Akron, O.
Sullivan Machinery Co., Chicago, Ill.
Williams Brothers, Ithaca, N. Y.

DRILLS — ROCK

Chicago Pneumatic Tool Co., Chicago, Ill.
Cleveland Pneumatic Tool Co., The, Cleveland, O.
Cleveland Rock Drill Co., Cleveland, O.
Hardsocg Wonder Drill Co., Ottumwa, Ia.
Helwig Mfg. Co., St. Paul, Minn.
Ingersoll-Rand Co., New York, N. Y.
LeGrand Mine Drill Works, Wilkes-Barre, Pa.
Rix Compressed Air & Drill Co., Los Angeles, Cal.
Sullivan Machinery Co., Chicago, Ill.

DYNAMITE; BLASTING POWDER

Ætna Explosives Co., Inc., New York, N. Y.
American Powder Mills, Boston, Mass.
Atlas Powder Co., Wilmington, Del.
Austin Powder Co., Cleveland, O.
du Pont de Nemours & Co., E. I., Wilmington, Del.
Giant Powder Co., San Francisco, Cal.
Hercules Powder Co., Wilmington, Del.
Illinois Powder Mfg. Co., St. Louis, Mo.
International Smokeless Powder & Chem. Co., New York, N. Y.
Rendrock Powder Co., New York, N. Y.
Roberts Powder Co., Shenandoah, Pa.
Shamokin Powder Co., Shamokin, Pa.
United States Powder Co., Terre Haute, Ind.

ELECTRIC MOTORS

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
C. & C. Electric & Mfg. Co., Garwood, N. J.
Crocker-Wheeler Co., Ampere, N. J.
Fairbanks, Morse & Co., Chicago, Ill.
General Electric Co., Schenectady, N. Y.
Triumph Electric Co., Cincinnati, O.
Western Electric Co., Chicago, Ill.
Westinghouse Electric & Mfg. Co., E. Pittsburg, Pa.

ELEVATING GRADERS

(See Grading Machines)

ENGINES — GAS, GASOLINE, KEROSENE AND OIL

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Armstrong Mfg. Co., Waterloo, Ia.
C. H. & E. Mfg. Co., Inc., Milwaukee, Wis.
Chicago Pneumatic Tool Co., Chicago, Ill.
Fairbanks Co., The, New York, N. Y.
Fairbanks, Morse & Co., Chicago, Ill.
Fuller & Johnson Mfg. Co., Madison, Wis.
Lambert Gas & Gasoline Engine Co., Anderson, Ind.
Otto Gas Engine Co., Philadelphia, Pa.
Standard Scale & Supply Co., Pittsburg, Pa.
Waterloo Gasoline Engine Co., Waterloo, Ia.
Worthington Pump & Mchy. Wks., New York, N. Y.

ENGINES — HOISTING

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Bay City Iron Co., Bay City, Mich.
Buffalo Hoist & Derrick Co., Buffalo, N. Y.
Byers Machine Co., John F., Ravenna, O.
Carpenter Co., Geo. B., Chicago, Ill.
Clyde Iron Works, Duluth, Minn.
Fairbanks, Morse & Co., Chicago, Ill.
Flory Mfg. Co., S., Bangor, Pa.
Hendy Iron Works, J, San Francisco, Cal.
Lidgerwood Mfg. Co., New York, N. Y.
Marsh & Co., Geo. C., Chicago, Ill.
Orr & Sembower, Reading, Pa.
Thomas Elevator Co., Chicago, Ill.

ENGINES — STEAM

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Ames Iron Works, Oswego, N. Y.
Buckeye Engine Co., Salem, O.
Clyde Iron Works, Duluth, Minn.
Erie City Iron Works, Erie, Pa.
Hewes & Phillips Iron Works, Newark, N. J.
Hooven-Owens-Rentschler Co., Hamilton, O.
Lawrence Machine Co., Lawrence, Mass.
Leffel & Co., James, Springfield, O.
Murray Iron Works Co., Burlington, Ia.
Nordberg Mfg. Co., Milwaukee, Wis.
Skinner Engine Co., Erie, Pa.
Sturtevant Co., B. F., Boston, Mass.
Vilter Mfg. Co., Milwaukee, Wis.
Watts-Campbell Co., Newark, N. J.

EXPLOSIVES

(See Dynamite)

FIRE EQUIPMENT

Chemical Engines

American-La France Fire Engine Co., Elmira, N. Y.
Badger Fire Extinguisher Co., Boston, Mass.
Castle, Co., James M., Philadelphia, Pa.
Simmons Co., John, New York, N. Y.

Fire Extinguishers

Allen Mfg. Co., W. D., Chicago, Ill.
Badger Chemical Mfg Co., Milwaukee, Wis.
Badger Fire Extinguisher Co., Boston, Mass.
Castle, Inc., James M., Philadelphia, Pa.
Fairbanks Co., The, New York, N. Y.
Foamite Firefoam Co., New York, N. Y.
Johns-Manville Co., H. W., New York, N. Y.
Pyrene Mfg. Co., New York, N. Y.
Salisbury & Co., Inc., W. H., Chicago, Ill.
Simmons Co., John, New York, N. Y.

Fire Hose

Castle, Inc., James M., Philadelphia, Pa.
Dominion Asbestos & Rubber Co., New York, N. Y.
Flexible Armored Hose Corp., Buffalo, N. Y.
Goodall Rubber Co., Inc., Philadelphia, Pa.
Simmons Co., John, New York, N. Y.
Union Asbestos & Rubber Co., Chicago, Ill.

FORGES — PORTABLE

Buffalo Forge Co., Buffalo, N. Y.
Carpenter & Co., Geo. B., Chicago, Ill.
Champion Blower & Forge Co., Lancaster, Pa.
Fairbanks Co., The, New York, N. Y.
Hauck Mfg Co., Brooklyn, N. Y.
Ingersoll-Rand Co., New York, N. Y.
Potts Co., P. H., Lancaster, Pa.
Ryerson & Son, Jos. T., Chicago, Ill.
Sturtevant Co., B. F., Boston, Mass.

FORKS — BALLAST

American Fork & Hoe Co., The, Cleveland, O.
Union Fork & Hoe Co., Columbus, O.

FORMS — STEEL

American Bridge Co., New York, N. Y.
Blaw-Knox Co., Pittsburg, Pa.
Butler Mfg. Co., Kansas City, Mo.

Heltzel Steel Form & Iron Co., Warren, O.
International Metal Mfg. Co., Philadelphia, Pa.
Western Pipe & Steel Co., San Francisco, Cal.

FURNACES

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Fairbanks Co., The, New York, N. Y.
Hauck Mfg. Co., Brooklyn, N. Y.
Leadite Co., Inc., Philadelphia, Pa.
Pollard, Jos. G., Brooklyn, N. Y.
Steubner, Geo. L., Long Island City, N. Y.
Union Iron Works, Hoboken, N. J.

GRADING MACHINES

Acme Road Machinery Co., Frankfort, N. Y.
Austin Mfg. Co., Chicago, Ill.
Good Roads Machinery Co., Kennett Square, Pa.
Kilbourne & Jacobs Mfg. Co., Columbus, O.
Russell Grader Mfg. Co., Minneapolis, Minn.
Stroud & Co., Omaha, Neb.
Western Wheeled Scraper Co., Aurora, Ill.

HEATERS — PORTABLE GRAVEL & SAND

Barber Asphalt Paving Co., Philadelphia, Pa.
Cummer & Son Co., The F. D., Cleveland, O.
Hauck Mfg. Co., Brooklyn, N. Y.
Indiana Foundry Co., Indiana, Pa.
Pangborn Corp., Hagerstown, Md.
Littleford Bros., Cincinnati, O.
Robertson & Co., William, Chicago, Ill.
Ruggles-Coles Engineering Co., New York, N. Y.

HOISTING ENGINES

(See Engines — Hoisting).

HOISTS — BUILDERS

American Hoist & Derrick Co., St. Paul, Minn.
C. H. & E. Mfg. Co., Milwaukee, Wis.
Clyde Iron Works, Duluth, Minn.
Hoisting Machinery Co., New York, N. Y.
Lidgerwood Mfg. Co., New York, N. Y.
Ransome-Leach Co., Dunellen, N. J.
Smith Co., The T. L., Milwaukee, Wis.
Standard Scale & Supply Co., Pittsburg, Pa.
Waterloo Cement Machinery Corp., Waterloo, Ia.

HOSE

Boston Belting Co., Boston, Mass.
Castle, Inc., Jas. M., Philadelphia, Pa.
Dominion Asbestos & Rubber Corp., New York, N. Y.
Goodall Rubber Co., Inc., Philadelphia, Pa.
Goodrich Rubber Co., B. F., Akron, O.
Simmons Co., John, New York, N. Y.
Union Asbestos & Rubber Co., Chicago, Ill.
Woodward, Wight & Co., Ltd., New Orleans, La.

HYDRAULIC MINING GIANTS

Hendy Iron Works, J., San Francisco, Cal.

JACKS — HYDRAULIC

Carpenter & Co., Geo. B., Chicago, Ill.
Dudgeon, Richard, New York, N. Y.
Duff Mfg. Co., The, Pittsburg, Pa.
Fairbanks Co., The, New York, N. Y.
Watson-Stilman Co., New York, N. Y.

JACKS — RATCHET

Buckeye Jack Mfg. Co., Alliance, O.
Buda Co., The, Chicago, Ill.
Duff Mfg. Co., The, Pittsburg, Pa.
McKiernan-Terry Drill Co., New York, N. Y.
Oliver Mfg. Co., Chicago, Ill.

JACKS — SCREW

Buckeye Jack Mfg. Co., Alliance, O.
Duff Mfg. Co., The, Pittsburg, Pa.
Fairbanks Co., The, New York, N. Y.
Millers Falls Co., Millers Falls, N. Y.
Spencer Otis Co., Chicago, Ill.
Wason Mfg. Co., Springfield, Mass.

LIGHTS — CONTRACTORS'

Adams & Westlake Co., The, Chicago, Ill.
Carbic Mfg. Co., Duluth, Minn.
Dayton Mfg. Co., Dayton, O.
Hauck Mfg. Co., Brooklyn, N. Y.
Macleod Co., The, Cincinnati, O.
Milburn Co., The Alexander, Baltimore, Md.
United States Headlight Co., Buffalo, N. Y.

LIGHTS — PORTABLE ELECTRIC PLANTS

Automatic Light Co., Inc., Ludington, Mich.
Sturtevant Co., B. F., Boston, Mass.

LOCOMOTIVE CRANES

American Bridge Co., New York, N. Y.
American Hoist & Derrick Co., St. Paul, Minn.
Austin Co., Inc., F. C., Chicago, Ill.
Brown Hoisting Machinery Co., The, Cleveland, O.
Bucyrus Co., So. Milwaukee, Wis.
Buffalo Hoist & Derrick Co., Buffalo, N. Y.
Osgood Co., The, Marion, O.
Pawling & Harnischfeger Co., Milwaukee, Wis.
Terry Mfg. Co., The Edw. F., New York, N. Y.
Thew Automatic Shovel Co., The, Lorain, O.
United States Crane Co., Chicago, Ill.

LOCOMOTIVES

American Locomotive Co., New York, N. Y.
Baldwin Locomotive Works, Philadelphia, Pa.
Davenport Locomotive Works, Davenport, Ia.
Dunkle Co., Arthur J., New York, N. Y.
Fate Co., The J. D., Plymouth, O.
Koppel Industrial Car & Equipment Co., Koppel, Pa.
Lima Locomotive Corp., Lima, O.
Mancha Storage Battery Locomotive Co., St. Louis, Mo.
Marsh & Co., Geo. C., Chicago, Ill.
Porter Co., H. K., Pittsburg, Pa.
Vulcan Iron Works, Wilkes Barre, Pa.

MIXERS — ASPHALT

Austin Co., Inc., The F. C., Chicago, Ill.
Barber Asphalt Paving Co., Philadelphia, Pa.
Koehring Machine Co., Milwaukee, Wis.
Lakewood Engineering Co., The, Cleveland, O.
Smith Co., The T. L., Milwaukee, Wis.
Turner Oil Co., Los Angeles, Cal.

MIXERS — CONCRETE

Abenague Machine Works, Westminster Station, Vt.
Austin Co., Inc., F. C., Chicago, Ill.
Blaw-Knox Co., Pittsburg, Pa.
Chain Belt Co., Milwaukee, Wis.
Eureka Machine Co., Lansing, Mich.
Jaeger Machine Co., The, Columbus, O.
Knickerbocker Co., Jackson, Mich.

Koehring Machine Co., Milwaukee, Wis.
Lakewood Engineering Co., The, Cleveland, O.
Lansing Co., Lansing, Mich.
Milwaukee Concrete Mixer Co., Milwaukee, Wis.
Ransome-Leach Co., Dunellen, N. J.
Smith Co., The T. L., Milwaukee, Wis.
Standard Scale & Supply Co., Pittsburg, Pa.
Waterloo Cement Machinery Corp., Waterloo, Ia.
Worthington Pump & Machinery Corp., New York, N. Y.

MOTOR TRUCKS

(See Automobiles)

PAINT SPRAYING MACHINES

Adams & Elting Co., Chicago, Ill.
Dayton Mfg. Co., Dayton, O.
De Vilbiss Mfg. Co., The, Toledo, O.
Goulds Mfg. Co., The, Seneca Falls, N. Y.
Ingersoll-Rand Co., New York, N. Y.
Macleod Co., The, Cincinnati, O.
Paasche Air Brush Co., Chicago, Ill.

PAULINS

Atlanta Tent & Awning Co., Atlanta, Ga.
Carpenter & Co., Geo. B., Chicago, Ill.
Eberhardt & Co., Indianapolis, Ind.
Hettrick Mfg. Co., The, Toledo, O.
Humphrey's Sons, R. A., Philadelphia, Pa.
Johnson, J. W., Chicago, Ill.
Stanley, Wm. W., New York, N. Y.
Textile Products Mfg. Co., St. Louis, Mo.

PIER AND FOUNDATION PLANT

Chicago Bridge & Iron Works, Chicago, Ill.
Foundation Co., New York, N. Y.
Great Lakes Dredge & Dock Co., Chicago, Ill.
Raymond Concrete Pile Co., New York.
Western Pipe & Steel Co. of Cal., San Francisco, Cal.

PILE DRIVERS

American Hoist & Derrick Co., St. Paul, Minn.
Bucyrus Co., The, So. Milwaukee, Wis.
Byers Machine Co., John F., Ravenna, O.
Industrial Works, Bay City, Mich.
Ingersoll-Rand Co., New York, N. Y.
Lidgerwood Mfg. Co., New York, N. Y.

McKiernan Terry Drill Co., New York, N. Y.
Orton & Steinbrenner, Chicago, Ill.
Union Iron Works, Hoboken, N. J.
Vulcan Iron Works, Chicago, Ill.

PILING — CONCRETE

Cranford Paving Co., Washington, D. C.
Cummings Structural Concrete Co., Pittsburg, Pa.
MacArthur Concrete Pile & Foundation Co., New York, N. Y.
Massey Concrete Products Corp., Chicago, Ill.
Raymond Concrete Pile Co., New York, N. Y.

PILING — CREOSOTED WOOD

American Creosote Works, Inc., New Orleans, La.
Central Creosoting Co., Chicago, Ill.
International Creosoting & Construction Co., Galveston, Tex.
Pacific Creosoting Co., Seattle, Wash.
Republic Creosoting Co., Indianapolis, Ind.
Wyckoff Pipe & Creosoting Co., New York, N. Y.

PILING — INTERLOCKING STEEL

Cambria Steel Co., Philadelphia, Pa.
Carnegie Steel Co., Pittsburg, Pa.
Lackawanna Steel Co., Lackawanna, N. Y.

PIPE — IRON AND STEEL

Baker, Hamilton & Pacific Co., San Francisco, Cal.
Clow & Sons, Jas. B., Chicago, Ill.
Cornell & Underhill, New York, N. Y.
Du Bois & Co., F. N., New York, N. Y.
Eagle Pipe Supply Co., Inc., New York, N. Y.
Frick & Lindsay Co., Pittsburg, Pa.
La Belle Iron Works, Steubenville, O.
National Tube Co., Pittsburg, Pa.
Wheeling Steel & Iron Co., Wheeling, W. V.

PLOWS

American Steel Scraper Co., Sidney, O.
Ames Plow Co., Boston, Mass.
Buffalo-Springfield Roller Co., Springfield, O.
Burch Plow Works Co., The, Crestline, O.
Deere & Co., Moline, Ill.
Fresno Agricultural Works, Fresno, Cal.
Hapgood Plow Co., Alton, Ill.
International Harvester Co., Chicago, Ill.
Oliver Chilled Plow Works, South Bend, Ind.

Vulcan Plow Co., Evansville, Ind.
Western Wheeled Scraper Co., Aurora, Ill.

POST HOLE DIGGERS

Columbus Handle & Tool Co., Columbus, Ind.
Empire Plow Co., Cleveland, O.
Iwan Brothers, South Bend, Ind.
Richards-Wilcox Mfg. Co., Aurora, Ill.
Wyoming Shovel Works, The, Wyoming, Pa.

PUMPS — CENTRIFUGAL

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Well Works, Aurora, Ill.
Blake-Knowles Works, New York, N. Y.
Cameron Steam Pump Works, A. S., New York, N. Y.
C. H. & E. Mfg. Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., Chicago, Ill.
Goulds Mfg. Co., The, Seneca Falls, N. Y.
Keystone Driller Co., Beaver Falls, Pa.
Morris Machine Works, Baldwinsville, N. Y.
Smith Co., The T. L., Milwaukee, Wis.
Taber Pump Co., Buffalo, N. Y.
Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Brothers Co., Chicago, Ill.
Yuba Mfg. Co., Marysville, Cal.

PUMPS — DIAPHRAGM

C. H. & E. Mfg. Co., Milwaukee, Wis.
Clow & Sons, Jas. B., Chicago, Ill.
Edson Mfg. Co., Boston, Mass.
Fairbanks Co., The, New York, N. Y.
Fairbanks, Morse & Co., Chicago, Ill.
Goulds Mfg. Co., Seneca Falls, N. Y.
Nye Steam Pump & Machinery Co., Chicago, Ill. (Trench)
Smith Co., The T. L., Milwaukee, Wis.
Worthington Pump & Machinery Corp., New York, N. Y.

RAIL AND TRACK SUPPLIES

Bethlehem Steel Co., So. Bethlehem, Pa.
Central Frog & Switch Co., Cincinnati, O.
Fairbanks, Morse & Co., Chicago, Ill.
Klein-Logan Co., The, Pittsburg, Pa.
Lackawanna Steel Co., Lackawanna, N. Y.
Lakewood Engineering Co., The, Cleveland, O.
Light Railway Equipment Co., Philadelphia, Pa.

Mechanical Mfg. Co., Chicago, Ill.
Morden Frog & Crossing Works, Chicago, Ill.
Standard Rail & Steel Co., St. Louis, Mo.
Track Specialties Co., New York, N. Y.
Zelnicker Supply Co., Walter A., St. Louis, Mo.

RIVETERS — PNEUMATIC

Chicago Pneumatic Tool Co., Chicago, Ill.
Cleveland Pneumatic Tool Co., Cleveland O.
Independent Pneumatic Tool Co., Chicago, Ill.
Ingersoll-Rand Co., New York, N. Y.
Keller Pneumatic Tool Co., Grand Haven, Mich.
Pittsburg Pneumatic Tool Co., The, Canton, O.
Watson-Stillman Co., New York, N. Y.

ROLLERS — ROAD

Acme Road Machinery Co., Frankfort, N. Y.
Austin Mfg. Co., Chicago, Ill.
Baker & Co., A. D., Swanton, O.
Barber Asphalt Paving Co., Philadelphia, Pa.
Buffalo-Springfield Roller Co., Springfield, O.
Erie Machine Shops, Erie, Pa.
Good Roads Machinery Co., Kennett Square, Pa.

ROPE — WIRE

American Steel & Wire Co., Chicago, Ill.
Fisher & Hayes Rope & Steel Co., Chicago, Ill.
Leschen & Sons Rope Co., A., St. Louis, Mo.
Roebling's Sons Co., John A., Trenton, N. J.
Waterbury Co., New York, N. Y.

SAND BLAST MACHINES

Macleod Co., The, Cincinnati, O.
Mott Sand Blast Mfg. Co., Chicago, Ill.
Pangborn Corp., Hagerstown, Md.
Rich Foundry Equipment Co., Chicago, Ill.

SAND AND GRAVEL WASHERS

Bicnantz Stone Co., Winona, Minn.
Link-Belt Co., Chicago, Ill.

SAW MILLS — PORTABLE

American Saw Mill Machinery Co., New York, N. Y.
Badger Gas & Gasoline Engine Co., Kansas City, Kan.
C. H. & E. Mfg. Co., Milwaukee, Wis.

Fuller & Johnson, Madison, Wis.
Knickerbocker Co., Jackson, Mich.

SCALES

Buffalo Scale Co., Buffalo, N. Y.
Cincinnati Scale Mfg. Co., Cincinnati, O.
Fairbanks, Morse & Co., Chicago, Ill.
Howe Scale Co., Rutland, Vt.
Standard Scale & Supply Co., The, Pittsburg, Pa.

SCARIFIERS

Austin Mfg. Co., Chicago, Ill.
Buffalo-Springfield Roller Co., Buffalo, N. Y.
Good Roads Machinery Co., Kennett Square, Pa.
Hyass & Co., Chas., New York, N. Y.

SCRAPERS

American Steel Scraper Co., Sidney, O.
Fresno Agricultural Works, Fresno, Cal.
Good Roads Machinery Co., Kennett Square, Pa.
Holt Mfg. Co., Stockton, Cal.
Kilbourne & Jacobs Mfg. Co., Columbus, O.
Lansing Company, Lansing, Mich.
Slusser-McLean Scraper Co., Sidney, O.
Stroud & Co., Omaha, Neb.
Western Wheeled Scraper Co., Aurora, Ill.

SCREENS — SAND, GRAVEL AND BROKEN STONE

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Audubon Wire Cloth Co., Inc., Audubon, N. J.
Austin Mfg. Co., Chicago, Ill.
Buffalo Wire Works Co., Buffalo, N. Y.
Chicago Perforating Co., Chicago, Ill.
Good Roads Machinery Co., Kennett Square, Pa.
Link-Belt Co., Chicago, Ill.
Littleford Bros., Cincinnati, O.
Sackett Screen & Chute Co., H. B., Chicago, Ill.
Western Wheeled Scraper Co., Aurora, Ill.

SHOVELS — HAND

Baldwin Tool Works, Parkersburg, W. Va.
Carpenter & Co., Geo. B., Chicago, Ill.
Fairbanks Co., The, New York, N. Y.
Pittsburg Shovel Co., Pittsburg, Pa.
Shapleigh Hardware Co., St. Louis, Mo.
Wyoming Shovel Works, The, Wyoming, Pa.

SHOVELS — STEAM

Bucyrus Co., The, So. Milwaukee, Wis.
Dunkle Co., Arthur J., New York, N. Y.
Fairbanks Steam Shovel Co., Marion, O.
Hoisting Machinery Co., New York, N. Y.
Hunt Co., C. W., New York, N. Y.
Keystone Driller Co., Beaver Falls, Pa.
Kilbourne & Jacobs Mfg. Co., Columbus, O.
Marion Steam Shovel Co., Marion, O.
Orton & Steinbrenner Co., Chicago, Ill.
Osgood Co., The, Marion, O.
Thew Automatic Shovel Co., The, Lorain, O.
Toledo Foundry & Machine Co., Toledo, O.

SKIPS

Lakewood Engineering Co., The, Cleveland, O.
Littleford Bros., Cincinnati, O.
Stuebner, Geo. L., Long Island City, N. Y.

SPRINKLING WAGON

Acme Road Machinery Co., Frankfort, N. Y.
Austin Co., Inc., F. C., Chicago, Ill.
Austin Mfg. Co., Chicago, Ill.
Birch, Jas. H., Burlington, N. J.
Streich & Bro. Co., A., Oshkosh, Wis.

STUMP PULLERS

Bennett & Co., H. L., Westerville, O.
Clyde Iron Works, Duluth, Minn.
Hercules Mfg. Co., Centerville, Ia.
Indiana Foundry Co., Indiana, Pa.
Milne Mfg. Co., Monmouth, Ill.
Niver Iron Works Co., Muscatine, Ia.
Sasgen Derrick Co., The, Chicago, Ill.
Smith Mfg. Co., La Crosse, Wis.
Swenson Grubber Co., Cresco, Ia.

SURVEYORS' AND ENGINEERS' INSTRUMENTS, ETC.

Ainsworth & Sons, Wm., Denver, Col.
Bausch & Lomb Optical Co., Rochester, N. Y.
Buff & Buff Mfg. Co., Boston, Mass.
Dietzgen Co., Eugene, Chicago, Ill.
Elliot Co., B. K., Pittsburg, Pa.
Gurley, W. & L. E., Troy, N. Y.
Keuffel & Esser Co., Hoboken, N. J.
Leitz Co., A., San Francisco, Cal.

Pease Co., The C. F., Chicago, Ill.
Williams, Brown & Earle, Inc., Philadelphia, Pa.
Young & Sons, Philadelphia, Pa.

TAMPERS — POWER

Lourie Mfg. Co., Springfield, Ill.
Pawling & Harnischfeger Co., Milwaukee, Wis.

TELEPHONES — DESPATCHING SYSTEMS & EQUIPMENT

Kellogg Switchboard & Supply Co., Chicago, Ill.
Stentor Electric Mfg. Co., Long Island City, N. Y.
Western Electric Co., Chicago, Ill.

TENTS AND CAMPING EQUIPMENT

American Tent & Awning Co., Minneapolis, Minn.
Ames-Harris-Neville, San Francisco, Cal.
Atlanta Tent & Awning Co., Atlanta, Ga.
Baker & Lockwood Mfg Co., Kansas City, Mo.
Carpenter & Co., Geo. B., Chicago, Ill.
Eberhardt & Co., Indianapolis, Ind.
Hettrick Mfg. Co., The, Toledo, O.
Johnson Co., J. W., Chicago, Ill.
Portland Tent & Awning Co., Portland, Ore.
Wheeler & Co., H. A., Boston, Mass.

TRACTORS — GASOLINE AND KEROSENE

Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Buffalo Pitts Co., Buffalo, N. Y.
Bullock Tractor Co., Chicago, Ill.
Dayton-Dick Co., Quincy, Ill.
Fairbanks, Morse Co., Chicago, Ill.
Garford Motor Truck Co., Lima, O.
Holt Mfg. Co., Stockton, Cal.
Little Giant Co., Mankato, Minn.
Mercury Mfg. Co., Chicago, Ill.

TRAILERS

Electric Wheel Co., Quincy, Ill.
Koppel Industrial Car Equipment Co., Koppel, Pa.
Lakewood Engineering Co., The Cleveland, O.
St. Louis Truck & Mfg. Co., St. Louis, Mo.

TRAILERS — AUTOMOBILE

Acme Wagon Works, Emigsville, Pa.
Columbia Motors Co., The, Detroit, Mich.

Columbia Motor Truck & Trailer Co., Pontiac, Mich.
Detroit Trailer Co., Detroit, Mich.
Glen Wagon & Car Corp., Cortland, N. Y.
Los Angeles Trailer Co., Los Angeles, Cal.
Ohio Trailer Co., Cleveland, Cal.
Troy Wagon Works, Troy, N. Y.

TRENCHING MACHINES

(See Ditchers)

TRUCKS — LOGGING AND LUMBER

Electric Wheel Co., Quincy, Ill.
Empire Mfg. Co., Quincy, Ill.
Holt Mfg. Co., Stockton, Cal.
International Harvester Co., Chicago, Ill.
Kilbourne & Jacobs Mfg. Co., Columbus, O.
Lewis-Shepard Co., Boston, Mass.
Mercury Mfg. Co., Chicago, Ill.
Ramapo Iron Works, Hillburn, N. Y.
Streich & Bro. Co., Oshkosh, Wis.
Troy Wagon Works Co., Troy, N. Y.
Zering Mfg. Co., The H., Cincinnati, O.

UNLOADING MACHINES

Bucyrus Co., So. Milwaukee, Wis.
Burch Plow Works Co., The, Crestline, O.
Lidgerwood Mfg. Co., New York, N. Y.
Marion Steam Shovel Co., Marion, O.
Rodger Ballast Car Co., Chicago, Ill.

WAGONS

Acme Wagon Co., Emigsville, Pa.
Auburn Wagon Co., Martinsburg, W. Va.
Burch Plow Works Co., The, Crestline, O.
Columbia Wagon Co., Columbia, Pa.
Electric Wheel Co., Quincy, Ill.
Holt Mfg. Co., Stockton, Cal.
Hoover Wagon Co., York, Pa.
Indiana Wagon Co., Lafayette, Ind.
International Harvester Co., Chicago, Ill.
Leonhardt Wagon Mfg. Co., Baltimore, Md.
Owensboro Wagon Co., Owensboro, Ky.
Randolph Wagon Works, Randolph, Wis.
Streich & Bro. Co., Oshkosh, Wis.
Tiffin Wagon Works Co., Tiffin, O.
Troy Wagon Works Co., Troy, N. Y.

WAGON LOADERS

Barber-Greene Co., Aurora, Ill.
Chain-Belt Co., Milwaukee, Wis.
Gifford-Wood Co., Hudson, N. Y.
Jeffrey Mfg. Co., Columbus, O.
Link-Belt Co., Chicago, Ill.
Ransome-Leach Co., Dunellen, N. J.
Smith Co., The T. L., Milwaukee, Wis.
Western Wheeled Scraper Co., Aurora, Ill.

WELDING AND CUTTING APPARATUS — ACETYLENE

American Welding Co., Chicago, Ill.
Carbic Mfg. Co., Duluth, Minn.
Davis-Bournonville Co., Jersey City, N. J.
Macleod Co., The, Cincinnati, O.
Milburn Co., The Alexander, Baltimore, Md.
Oxweld Railroad Service Co., Chicago, Ill.
Safety Car Heating & Lighting Co., New York, N. Y.

WHEELBARROWS

American Steel Scraper Co., Sidney, O.
Chattanooga Wheelbarrow Co., Chattanooga, Tenn.
Consolidated Iron Works, Hoboken, N. J.
Continental Car Co. of America, Louisville, Ky.
Kilbourne & Jacobs Mfg. Co., Columbus, O.
Sterling Wheelbarrow Co., Milwaukee, Wis.
Union Iron Works, Hoboken, N. J.
Western Iron Works, San Francisco, Cal.

WINCHES

American Hoist & Derrick Co., St. Paul, Minn.
Carpenter & Co., Geo. B., Chicago, Ill.
Clyde Iron Works, Duluth, Minn.
Hoisting Machinery Co., New York, N. Y.
Sasgen Derrick Co., Chicago, Ill.
Star Machinery Co., Seattle, Wash.

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